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PAPER

Synthesis of 2,3,5,6-tetrasubstituted tetrahydropyrans *via* (3,5)-oxonium-ene reaction†

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An efficient method for the synthesis of 2,3,5,6-tetrasubstituted tetrahydropyrans has been developed from the reaction of aldehydes and ethyl 2-(1-hydroxyalkyl/hydroxy(phenyl)methyl)-5-methylhex-4-enoate using (3,5)-oxonium-ene reaction promoted by boron trifluoride etherate in good yields under mild conditions.

Introduction

The tetrahydropyrans are important structural features in synthetic organic chemistry as they are core units of many biologically active molecules and natural products.[1] The polyether antibiotics, marine toxins and pheromones are such biologically active natural products.[2] The 2,3,5,6-tetrasubstituted tetrahydropyran units are found in antibiotics such as FR-901464 and X-206.[3] Tetrahydropyrans are prepared by hetero-Diels–Alder reactions,[4] manipulations of carbohydrates,[5] intramolecular Michael reactions,[6] Prins cyclization[7] and other methods.[8] Several 2,4-, 2,3,6-, 2,4,5-, 2,4,6-, 2,3,4,6- and 2,4,5,6-substituted tetrahydropyrans have been synthesized using these approaches. To our knowledge the synthetic procedures for the synthesis of 2,3,5,6-tetrasubstituted tetrahydropyrans are limited.[9] Oxonium-ene reactions are considered as powerful tools for the construction of various cyclic ethers.[10] Recently, we have demonstrated the utility of the oxonium-ene reaction for the synthesis of 2,2,5,6- and 2,4,6-substituted tetrahydropyrans and bicyclic ethers.[11] Herein, we now report an efficient methodology for the synthesis of 2,3,5,6-tetrasubstituted tetrahydropyrans from aldehydes and ethyl 2-(1-hydroxyalkyl/hydroxy(phenyl)methyl)-5-methylhex-4-enoate using (3,5)-oxonium-ene reaction promoted by boron trifluoride etherate under mild conditions. Our aim is to introduce an ester group onto the tetrahydropyran ring, from which diverse functionalization could be achieved in the tetrahydropyran molecule and therefore, ethyl 2-(1-hydroxyalkyl/hydroxy(phenyl)methyl)-5-methylhex-4-enoate could be considered as starting materials for the synthesis of tetrasubstituted tetrahydropyrans.

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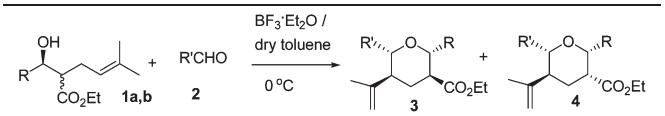
Results and discussion

The reaction of alcohols ethyl 2-(1-hydroxyethyl)-5-methylhex-4-enoate **1a** (1 : 1 diastereomeric mixture) and ethyl 2-(1-hydroxypropyl)-5-methylhex-4-enoate **1b** (1 : 1 diastereomeric mixture) with different aldehydes in dry toluene in the presence of boron trifluoride etherate afforded a mixture of diastereomeric products **3** and **4** with an epimeric center on C-3 bearing an ester group (Table 1). In all the cases the diastereomeric ratio was 1 : 1. The diastereomers **3** and **4** could be separated by column chromatography. The stereochemistry of **3** and **4** was determined by NOE experiment and X-ray crystallographic analysis.[12] In the ^{1}H NMR spectrum the axial proton at position C-4 (H_{4a}) of **3a** shows a ddd with coupling constants 12.8, 12.4 and 12.4 Hz at δ 1.99 ppm, which indicates that the proton is coupled with two neighbouring axial protons H_{3a} and H_{5a}. On the other hand same proton (H_{4a}) of **4a** shows a ddd with coupling constants 13.6, 12.8 and 5.2 Hz at δ 1.90 ppm, which is indicative of coupling with one axial H_{5a} and one equatorial proton H_{3e}. This clearly indicates that **3a** and **4a** are epimeric at C-3. A comparison of other ^{1}H NMR signals of **3a** and **4a** is shown in Table 2.

The mechanism for the formation of two diastereomers **3** and **4** from alcohols **1a** and **1b** can be explained as follows (Scheme 1). Here, Lewis acid activates the aldehyde **2** for the nucleophilic attack by alcohols **1a** and **1b** to give acetals **5** and **6**, which after decomposition generate oxocarbenium ions **7** and **8**. The species **7** and **8**, after (3,5)-oxonium-ene reaction, form carbocations **9** and **10**, which after deprotonation give **3** and **4** in equal amounts.

The reaction was also performed with *anti*- and *syn*-alcohols **1c** and **1d**. The reaction of aldehyde **2** with *anti*-ethyl

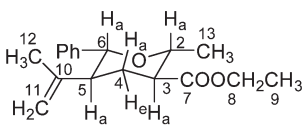
Table 1 Synthesis of 2,3,5,6-tetrasubstituted tetrahydropyrans



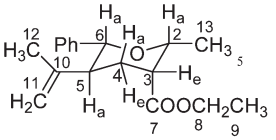
Entry	Alcohol **1a**, R = Me, **1b**, R = Et	Aldehyde R′=	Time (min)	**3** + **4** Yield[a,b] (%)
a	Me	C_6H_5	60	78
b	Me	*p*-Me-C_6H_4	60	72
c	Me	*p*-Br-C_6H_4	60	66
d	Me	*p*-Cl-C_6H_4	60	62
e	Me	*p*-F-C_6H_4	60	64
f	Me	*p*-NO_2-C_6H_4	60	62
g	Me	*p*-MeO_2C-C_6H_4	60	68
h	Me	C_3H_7	30	86
i	Me	C_6H_{13}	30	82
j	Me	$(CH_3)_2CHCH_2$	30	84
k	Et	C_6H_5	90	74
l	Et	*p*-Me-C_6H_4	90	70
m	Et	*p*-MeO_2C-C_6H_4	90	68
n	Et	C_3H_7	50	88
o	Et	C_6H_{13}	50	80
p	Et	$(CH_3)_2CHCH_2$	50	84

[a] The ratio of formation of **3** and **4** is (1 : 1) and is determined by ^{1}H NMR of crude products. [b] Total isolated yield of **3** and **4**. The compounds were characterized by IR, ^{1}H, ^{13}C, ^{19}F NMR and mass spectroscopy.

Table 2 Comparison of ^{1}H NMR data of **3a** and **4a**



3a



4a

Assignment	δ (ppm)	Multiplicity	Coupling constants (Hz)
13-CH_3	1.27 (**3a**)	d	7.2
	1.32 (**4a**)	d	6.4
9-CH_3	1.28 (**3a**)	t	7.2
	1.33 (**4a**)	t	7.2
12-CH_3	1.43 (**3a**)	s	—
	1.42 (**4a**)	s	—
H_{4a}	1.99 (**3a**)	ddd	12.8, 12.4, 12.4
	1.90 (**4a**)	ddd	13.6, 12.8, 5.2
H_{4e}	2.09 (**3a**)	ddd	12.8, 4.0, 4.0
	2.14 (**4a**)	ddd	13.6, 4.0, 4.0
H_{3a}	2.33 (**3a**)	ddd	12.4, 10.4, 4.0
H_{3e}	2.60–2.67 (**4a**)	m	—
H_{5a}	2.46 (**3a**)	ddd	12.4, 10.0, 4.0
	3.01 (**4a**)	ddd	12.8, 12.4, 3.6
H_{2a}	3.76–3.85 (**3a**)	m	—
	3.82–3.89 (**4a**)	m	—
8-CH_2-	4.17 (**3a**)	q	7.2
	4.14–4.28 (**4a**)	m (overlapping)	—
H_{6a}	4.29 (**3a**)	d	10.0
	4.14–4.28 (**4a**)	m (overlapping)	—
11H	4.62 (**3a**)	brs	—
	4.63 (**4a**)	brs	—
11H	4.66 (**3a**)	brs	—
	4.67 (**4a**)	brs	—
Ar–H	7.22–7.32 (**3a**)	m	—
	7.22–7.25, 7.26–7.31, 7.32–7.36 (**4a**)	m	—

2-(hydroxy(phenyl)methyl)-5-methylhex-4-enoate **1c** gave single diastereomer **11** in good yields (Table 3).

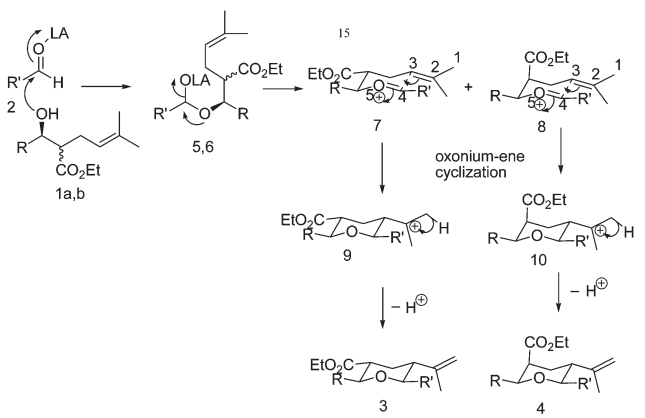
Similarly, the reaction of *syn*-ethyl 2-(hydroxy(phenyl) methyl)-5-methylhex-4-enoate **1d** gave single diastereomer **12** in good yields (Table 4). The stereochemistry of the compounds was determined by NOE experiment and X-ray crystallographic analysis.[12]

It was observed from Tables 1,3–4 that aliphatic aldehydes gave better yields compared to the aromatic aldehydes. The aromatic aldehydes having electron-withdrawing groups gave lower yield than the aromatic aldehydes having electron-donating groups. This might be due to the better stability imparted to the oxocarbenium ions **7** and **8** (Scheme 1) by the aliphatic aldehydes and aromatic aldehydes having electron donating groups on the aromatic ring, which in turn are attacked by the double bond efficiently. On the other hand, aromatic aldehydes having electron withdrawing groups on the ring destabilize the oxocarbenium ions **7** and **8**.

The mechanisms for the formation of 2,3,5,6-substituted tetrahydropyrans **11** and **12** is similar to the one shown in Scheme 1.

The reaction of salicylaldehyde with *anti*/*syn*-ethyl 2-(hydroxy (phenyl)methyl)-5-methylhex-4-enoate, **1c**/**1d** gave tricyclic chromene compounds **13** and **14** with 58% and 55% yields, respectively (Scheme 2). Here in both the cases 30% unreacted starting materials were recovered. The structure and stereochemistry of the compounds were determined from NOE experiment and X-ray crystallographic analysis.†[12]

The mechanism for the formation of chromenes is shown in Scheme 3. Here the carbocation **17** formed after oxonium-ene

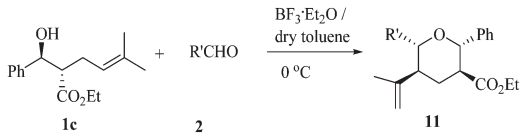


where R = Me, Et

Scheme 1 Mechanism for the formation of tetrahydropyrans.

cyclization of **16** is attacked by nucleophilic phenolic group to form the tricyclic chromene compounds **13** and **14**. The mechanism is in accordance with the mechanism reported in the literature.[10c,11c]

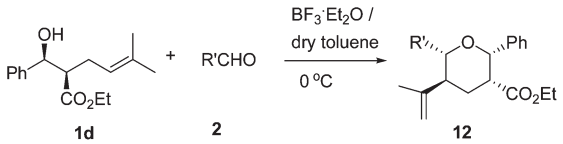
Table 3 Synthesis of 2,3,5,6-tetrasubstituted tetrahydropyrans from *anti*-alcohol **1c**



Entry	Aldehyde R′=	Time (min)	Product	Yield[a] (%)
1	C_6H_5 (a)	60	**11a**	80
2	*p*-Me-C_6H_4 (b)	60	**11b**	70
3	*p*-MeO-C_6H_4 (c)	60	**11c**	74
4	*p*-F-C_6H_4 (d)	60	**11d**	60
5	*p*-NO_2-C_6H_4 (e)	60	**11e**	60
6	*p*-MeO_2C-C_6H_4 (f)	60	**11f**	65
7	C_2H_5 (g)	30	**11g**	92
8	$(CH_3)_2CHCH_2$ (h)	30	**11h**	87

[a] Yields refer to isolated yield. The compounds were characterized by IR, ^1H, ^{13}C, ^{19}F NMR and mass spectroscopy.

Table 4 Synthesis of 2,3,5,6-tetrasubstituted tetrahydropyrans from *syn*-alcohol **1d**



Entry	Aldehyde R′=	Time (min)	Product	Yield[a] (%)
1	*p*-Me-C_6H_4 (a)	60	**12a**	72
2	*p*-Br-C_6H_4 (b)	60	**12b**	58
3	*p*-Cl-C_6H_4 (c)	60	**12c**	55
4	*p*-MeO_2C-C_6H_4 (d)	60	**12d**	62
5	C_3H_7 (e)	30	**12e**	90
6	*cyclo*-C_6H_{11} (f)	30	**12f**	80

[a] Yields refer to isolated yield. The compounds are characterized by IR, ^1H, ^{13}C NMR and mass spectroscopy.

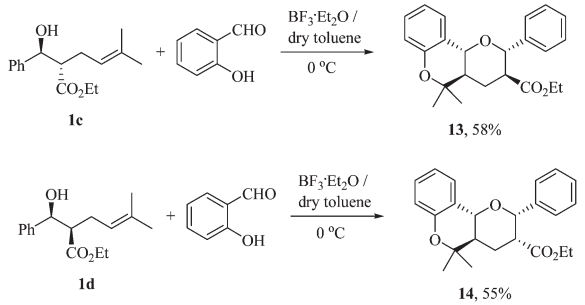
Conclusions

In conclusion we have developed an efficient methodology for the synthesis of 2,3,5,6-tetrasubstituted tetrahydropyrans from aldehydes and δ-unsaturated alcohols using (3,5)-oxonium-ene reaction mediated by boron trifluoride etherate in good yields under mild conditions. Synthesis of highly substituted tetrahydropyrans is of great importance in organic synthesis as they are the key structural features in many biologically active natural products and pharmaceuticals. Therefore, the present method would be beneficial to synthetic chemistry community.

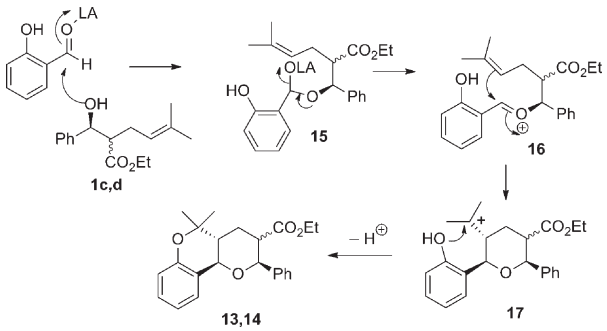
Experimental section

General procedure for the synthesis of 2,3,5,6-tetrasubstituted tetrahydropyrans and chromenes

To a solution of aldehyde (1 mmol, 1 equiv.) in dry toluene (2 mL) at 0 °C was added boron trifluoride etherate (1.1 mmol, 1.1 equiv.). To this solution ethyl 2-(1-hydroxyalkyl/hydroxy (phenyl)methyl)-5-methylhex-4-enoate (1 mmol, 1 equiv.) in dry toluene (2 mL) was added drop by drop over 5 min. The reaction mixture was stirred at that temperature for a specified time. The progress of the reaction was monitored by TLC with ethyl acetate and hexane as eluents. After completion of the reaction, it was quenched with saturated solution of $NaHCO_3$. The product was extracted with ethyl acetate (30 mL) and then washed with water (15 mL) and brine (15 mL). The organic layer was dried (Na_2SO_4) and evaporated to leave the crude product, which was purified by short column chromatography over silica gel to give the title compounds.



Scheme 2 Reaction with salicylaldehyde.



Scheme 3 Mechanism for the formation of chromenes.

Synthesis of (2*R**,3*S**,5*S**,6*R**)/(2*R**,3*R**,5*S**,6*R**)-ethyl tetrahydro-2-methyl-6-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (3a & 4a)

To a solution of benzaldehyde (106 mg, 1.00 mmol) in dry toluene (2 mL) at 0 °C was added boron trifluoride etherate (156 mg, 1.10 mmol). To this solution ethyl 2-(1-hydroxyethyl)-5-methylhex-4-enoate (200 mg, 1 mmol) in dry toluene (2 mL) was added drop by drop over 5 min. The reaction mixture was stirred at that temperature for another 55 min. The progress of the reaction was monitored by TLC with ethyl acetate and hexane (1 : 24) as eluents. After completion of the reaction, it was quenched with saturated solution of $NaHCO_3$. The product was extracted with ethyl acetate (30 mL) and then washed with water (15 mL) and brine (15 mL). The organic layer was dried (Na_2SO_4) and evaporated to leave the crude products, which were separated by column chromatography over silica gel to give **3a** (115 mg, 40%) and **4a** (110 mg, 38%) as colourless oils.

(2*R,3*S**,5*S**,6*R**)-Ethyl tetrahydro-2-methyl-6-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (3a)**

Colourless oil (115 mg, 40%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.27 (d, J = 6.4 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 1.43 (s, 3 H), 1.99 (ddd, J = 12.8, 12.4 and 12.4 Hz, 1 H), 2.09 (ddd, J = 12.8, 4.0 and 4.0 Hz, 1 H), 2.33 (ddd, J = 12.4, 10.4 and 4.0 Hz, 1 H), 2.46 (ddd, J = 12.4, 10.0 and 4.0 Hz, 1 H), 3.76–3.85 (m, 1 H), 4.17 (q, J = 7.2 Hz, 2 H), 4.29 (d, J = 10.0 Hz, 1 H), 4.62 (brs, 1 H), 4.66 (brs, 1 H), 7.22–7.32(m, 5 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.4, 20.3, 21.5, 34.0, 49.5, 49.8, 60.6, 75.1, 84.1, 113.0, 127.5, 128.0, 128.3, 140.7, 145.1, 173.9; IR (KBr, neat): 2978, 2933, 1730, 1644, 1452, 1375, 1175, 1102, 1064, 755, 699 cm^{-1}. HRMS (APCI) cald for $C_{18}H_{24}O_3$ $(M + H)^+$ requires 289.1803; found 289.1803. APCI-MS: *m*/*z* (relative intensity): 289.2 ($(M + H)^+$, 42%), 287.2 (11), 243.1 (9), 197.1 (9), 157.1 (26), 124.1 (100), 123.1 (44), 82.0 (25).

(2*R,3*S**,5*S**,6*R**)-Ethyl tetrahydro-2-methyl-5-(prop-1-en-2-yl)-6-*p*-tolyl-2*H*-pyran-3-carboxylate (3b)**

Colourless oil (115 mg, 38%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.24 (d, J = 6.4 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 1.45 (s, 3 H), 1.97 (ddd, J = 12.8, 12.6 and 12.4 Hz, 1 H), 2.10 (ddd, J = 12.8, 4.0 and 3.6 Hz, 1 H), 2.30 (s, 3 H), 2.34 (ddd, J = 12.6, 12.4 and 3.6 Hz, 1 H), 2.44 (ddd, J = 12.4, 10.4 and 4.0 Hz, 1 H), 3.75–3.84 (m, 1 H), 4.16 (q, J = 7.2 Hz, 2 H), 4.26 (d, J = 10.4 Hz, 1 H), 4.63 (brs, 1 H), 4.65 (brs, 1 H), 7.09 (d, J = 7.6 Hz, 2 H), 7.17 (d, J = 8.0 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.4, 20.3, 21.3, 21.5, 34.1, 49.3, 49.8, 60.6, 75.1, 83.8, 112.9, 127.5, 129.0, 137.6, 137.7, 145.3, 174.0; IR (KBr, neat): 2977, 2929, 2857, 1731, 1375, 1101, 1065, 812 cm^{-1}. HRMS (APCI) cald for $C_{19}H_{26}O_3$ $(M + H)^+$ requires 303.1960; found 303.1952. APCI-MS: *m*/*z* (relative intensity): 303.2 ($(M + H)^+$, 50%), 285.2 (27), 211.1 (34), 173.1 (19), 157.1 (27), 124.1 (100), 82.0 (44).

(2*R,3*S**,5*S**,6*R**)-Ethyl 6-(4-bromophenyl)-tetrahydro-2-methyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (3c)**

Colourless oil (132 mg, 36%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.24 (d, J = 6.0 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 1.45 (s, 3 H), 1.98 (ddd, J = 12.8, 12.4 and 12.4 Hz, 1 H), 2.09 (ddd, J = 12.8, 4.0 and 3.6 Hz, 1 H), 2.25 (ddd, J = 12.8, 11.6 and 3.6 Hz, 1 H), 2.44 (ddd, J = 12.4, 10.0 and 4.0 Hz, 1 H), 3.75–3.83 (m, 1 H), 4.17 (q, J = 7.2 Hz, 2 H), 4.26 (d, J = 10.0 Hz, 1 H), 4.62 (brs, 1 H), 4.68 (brs, 1 H), 7.17 (d, J = 8.4 Hz, 2 H), 7.42 (d, J = 8.4 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.4, 20.3, 21.6, 33.9, 49.7 (2C), 60.7, 75.2, 83.3, 113.4, 121.8, 129.2, 131.4, 139.9, 144.8, 173.9; IR (KBr, neat): 2977, 2931, 2866, 1729, 1644, 1375, 1175, 1102, 1069, 894, 810 cm^{-1}. HRMS (APCI) cald for $C_{18}H_{23}BrO_3$ $(M + H)^+$ requires 367.0909; found 367.0905 (^{79}Br). APCI-MS: *m*/*z* (relative intensity): 369.1 ($(M + H)^+$, 4%, ^{81}Br), 367.1 ($(M + H)^+$, 6, ^{79}Br), 303.2 (5), 211.2 (3), 201.1 (26), 157.1 (19), 124.1 (100).

(2*R,3*S**,5*S**,6*R**)-Ethyl 6-(4-chlorophenyl)-tetrahydro-2-methyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (3d)**

Colourless oil (106 mg, 33%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.25 (d, J = 6.0 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 1.45 (s, 3 H), 1.97 (ddd, J = 12.8, 12.8 and 12.4 Hz, 1 H), 2.09 (ddd, J = 12.8, 4.0 and 3.6 Hz, 1 H), 2.25 (ddd, J = 12.8, 12.8 and 3.6 Hz, 1 H), 2.44 (ddd, J = 12.4, 10.0 and 4.0 Hz, 1 H), 3.76–3.84 (m, 1 H), 4.17 (q, J = 7.2 Hz, 2 H), 4.27 (d, J = 10.0 Hz, 1 H), 4.62 (brs, 1 H), 4.68 (brs, 1 H), 7.23 (d, J = 8.4 Hz, 2 H), 7.26 (d, J = 8.8 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.4, 20.3, 21.6, 33.9, 49.7 (2C), 60.7, 75.2, 83.2, 113.4, 128.5, 128.8, 133.6, 139.3, 144.7, 173.8; IR (KBr, neat): 2978, 2932, 2866, 1729, 1645, 1449, 1376, 1175, 1099, 1067, 894, 824 cm^{-1}. HRMS (APCI) cald for $C_{18}H_{23}ClO_3$ $(M + H)^+$ requires 323.1414; found 323.1407 (^{35}Cl). APCI-MS: *m*/*z* (relative intensity): 325.1 ($(M + H)^+$, 3%, ^{37}Cl), 323.2 ($(M + H)^+$, 10, ^{35}Cl), 267.2 (10), 200.1 (9), 199.1 (66), 181.1 (100), 157.1 (18), 124.1 (83).

(2*R,3*S**,5*S**,6*R**)-Ethyl 6-(4-fluorophenyl)-tetrahydro-2-methyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (3e)**

Colourless oil (89 mg, 29%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.25 (d, J = 6.0 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 1.44 (s, 3 H), 1.97 (ddd, J = 14.0, 12.8 and 12.0 Hz, 1 H), 2.09 (ddd, J = 14.0, 4.0 and 4.0 Hz, 1 H), 2.27 (ddd, J = 12.8, 10.4 and 4.0 Hz, 1 H), 2.44 (ddd, J = 12.0, 10.0 and 4.0 Hz, 1 H), 3.76–3.84 (m, 1 H), 4.17 (q, J = 7.2 Hz, 2 H), 4.28 (d, J = 10.0 Hz, 1 H), 4.62 (brs, 1 H), 4.67 (brs, 1 H), 6.98 (t, J = 8.4 Hz, 2 H), 7.24–7.28 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.4, 20.3, 21.5, 33.9, 49.7, 49.8, 60.7, 75.2, 83.2, 113.2, 115.0 (d, J = 21.3 Hz), 129.1 (d, J = 8.4 Hz), 136.7, 144.9, 162.5 (d, J = 244.1 Hz), 173.8; ^{19}F NMR (376 MHz, $CDCl_3/C_6F_6$): δ −218.70–(−218.62) (m, 1F); IR (KBr, neat): 2979, 2934, 2867, 1729, 1644, 1450, 1376, 1176, 1102, 1065, 832, 788 cm^{-1}. HRMS (APCI) cald for $C_{18}H_{23}FO_3$ $(M + H)^+$ requires 307.1709; found 307.1715. APCI-MS: *m*/*z* (relative intensity): 307.2 ($(M + H)^+$, 42%), 289.2 (12), 215.1 (12), 184.1 (14), 157.1 (53), 124.1 (100).

(2*R,3*S**,5*S**,6*R**)-Ethyl tetrahydro-2-methyl-6-(4-nitrophenyl)-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (3f)**

Colourless oil (117 mg, 35%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.27 (d, J = 6.0 Hz, 3 H), 1.29 (t, J = 7.2 Hz, 3 H), 1.47 (s, 3 H), 1.99 (ddd, J = 13.2, 12.5 and 12.4 Hz, 1 H), 2.12 (ddd, J = 13.2, 3.6 and 3.6 Hz, 1 H), 2.24 (ddd, J = 12.8, 12.5 and 3.6 Hz, 1 H), 2.47 (ddd, J = 12.4, 10.0 and 3.6 Hz, 1 H), 3.78–3.87 (m, 1 H), 4.18 (q, J = 7.2 Hz, 2 H), 4.41 (d, J = 10.0 Hz, 1 H), 4.61 (brs, 1 H), 4.70 (brs, 1 H), 7.46 (d, J = 8.8 Hz, 2 H), 8.16 (d, J = 8.8 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.4, 20.2, 21.6, 33.7, 49.5, 50.2, 60.9, 75.3, 82.8, 114.0, 123.5, 128.3, 144.1, 147.7, 148.2, 173.6; IR (KBr, neat): 2975, 2935, 2871, 1726, 1643, 1519, 1372, 1344, 1170, 1101, 1060, 849 cm^{-1}. HRMS (APCI) cald for $C_{18}H_{23}NO_5$ $(M + H)^+$ requires 334.1654; found 334.1652. APCI-MS: *m*/*z* (relative intensity): 334.2 ($(M + H)^+$, 1%), 263.2 (3), 245.2 (12), 201.2 (13), 177.1 (25), 125.1 (10), 124.1 (100), 99.0 (27).

(2*R,3*S**,5*S**,6*R**)-Ethyl 6-(4-(methoxycarbonyl)phenyl)-tetrahydro-2-methyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (3g)**

Colourless oil (125 mg, 36%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.27 (d, J = 6.0 Hz, 3 H), 1.29 (t, J = 7.2 Hz, 3 H), 1.43 (s, 3 H), 1.99 (ddd, J = 12.8, 12.8 and 12.4 Hz, 1 H), 2.10 (ddd, J = 12.8, 4.0 and 3.6 Hz, 1 H), 2.28 (ddd, J = 12.8, 12.0 and 4.0 Hz, 1 H), 2.47 (ddd, J = 12.4, 10.0 and 3.6 Hz, 1 H), 3.78–3.86 (m, 1 H), 3.90 (s, 3 H), 4.17 (q, J = 7.2 Hz, 2 H), 4.35 (d, J = 10.0 Hz, 1 H), 4.60 (brs, 1 H), 4.66 (brs, 1 H), 7.36 (d, J = 8.4 Hz, 2 H), 7.97 (d, J = 8.4 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.3, 20.1, 21.5, 33.7, 49.5, 49.8, 52.1, 60.6, 75.0, 83.4, 113.3, 127.4, 129.5, 130.2, 144.4, 145.8, 167.0, 173.6; IR (KBr, neat): 2979, 2936, 2867, 1725, 1645, 1437, 1376, 1279, 1102, 1066, 896, 772, 706 cm^{-1}. HRMS (APCI) cald for $C_{20}H_{26}O_5$ $(M + H)^+$ requires 347.1858; found 347.1865. APCI-MS: *m*/*z* (relative intensity): 347.2 ($(M + H)^+$, 8%), 315.2 (3), 202.2 (10), 201.1 (75), 181.1 (11), 157.1 (5), 124.1 (100), 123.1 (54), 82.0 (47).

(2*R,3*S**,5*S**,6*S**)-Ethyl tetrahydro-2-methyl-5-(prop-1-en-2-yl)-6-propyl-2*H*-pyran-3-carboxylate (3h)**

Colourless oil (115 mg, 45%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.88 (t, J = 7.2 Hz, 3 H), 1.19 (d, J = 6.4 Hz, 3 H), 1.26 (t, J = 7.2 Hz, 3 H), 1.27–1.35 (m, 2 H), 1.42–1.56 (m, 2 H), 1.67 (s, 3 H), 1.80 (ddd, J = 12.8, 12.4 and 12.0 Hz, 1 H), 1.91 (ddd, J = 12.8, 4.0 and 3.6 Hz, 1 H), 1.99 (ddd, J = 12.4, 10.0 and 3.6 Hz, 1 H), 2.27 (ddd, J = 12.0, 10.0 and 4.0 Hz, 1 H), 3.31 (dt, J = 9.2 and 7.2 Hz, 1 H), 3.54–3.63 (m, 1 H), 4.13 (q, J = 7.2 Hz, 2 H), 4.76 (brs, 1 H), 4.77 (brs, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.1, 14.3, 18.8, 20.2(2C), 33.8, 35.5, 48.8, 49.8, 60.5, 74.5, 79.5, 112.7, 146.1, 174.1; IR (KBr, neat): 2960, 2937, 2872, 1732, 1644, 1452, 1376, 1150, 1113, 1037, 893, 750 cm^{-1}. HRMS (APCI) cald for $C_{15}H_{26}O_3$ $(M + H)^+$ requires 255.1960; found 255.1964. APCI-MS: *m*/*z* (relative intensity): 255.2 ($(M + H)^+$, 17%), 254.7 (100), 179.7 (7), 156.8 (4), 123.8 (41).

(2*R,3*S**,5*S**,6*S**)-Ethyl 6-hexyl-tetrahydro-2-methyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (3i)**

Colourless oil (127 mg, 43%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.87 (t, J = 6.8 Hz, 3 H), 1.20 (d, J = 6.0 Hz, 3 H), 1.24–1.34 (m, 8 H), 1.26 (t, J = 7.2 Hz, 3 H), 1.47–1.52 (m, 2 H), 1.67 (s, 3 H), 1.80 (ddd, J = 12.8, 12.4 and 12.0 Hz, 1 H), 1.91 (ddd, J = 12.8, 4.0 and 3.6 Hz, 1 H), 1.97 (ddd, J = 12.4, 10.4 and 3.6 Hz, 1 H), 2.28 (ddd, J = 12.0, 10.4 and 4.0 Hz, 1 H), 3.29 (dt, J = 8.8 and 8.4 Hz, 1 H), 3.55–3.64 (m, 1 H), 4.13 (q, J = 7.2 Hz, 2 H), 4.75 (brs, 1 H), 4.77 (brs, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.3, 14.4, 20.2(2C), 22.9, 25.7, 29.5, 32.1, 33.5, 33.9, 48.8, 49.8, 60.6, 74.6, 79.9, 112.8, 146.1, 174.2; IR (KBr, neat): 2929, 2858, 1732, 1643, 1455, 1376, 1174, 1115, 1035, 892 cm^{-1}. HRMS (APCI) cald for $C_{18}H_{32}O_3$ $(M + H)^+$ requires 297.2429; found 297.2424. APCI-MS: *m*/*z* (relative intensity): 297.2 ($(M + H)^+$, 45%), 211.2 (11), 180.1 (4), 150.1 (10), 124.1 (100), 123.1 (59), 82.0 (43).

(2*R,3*S**,5*S**,6*S**)-Ethyl tetrahydro-6-isobutyl-2-methyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (3j)**

Colourless oil (110 mg, 41%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.85 (d, J = 6.8 Hz, 3 H), 0.89 (d, J = 6.8 Hz, 3 H), 1.19 (d, J = 6.0 Hz, 3 H), 1.24–1.30 (m, 2 H), 1.26 (t, J = 7.2 Hz, 3 H), 1.66 (s, 3 H), 1.76–1.99 (m, 4 H), 2.28 (ddd, J = 10.0, 10.0 and 4.0 Hz, 1 H), 3.37 (dt, J = 10.0 and 7.6 Hz, 1 H), 3.54–3.62 (m, 1 H), 4.12 (q, J = 7.2 Hz, 2 H), 4.75 (brs, 1 H), 4.77 (brs, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.4, 20.1, 20.2, 21.6, 24.0, 24.2, 33.9, 42.4, 49.3, 49.8, 60.5, 74.6, 77.9, 112.8, 146.1, 174.1; IR (KBr, neat): 2955, 2928, 2870, 1732, 1644, 1451, 1374, 1176, 1115, 1068, 1035, 892 cm^{-1}. HRMS (APCI) cald for $C_{16}H_{28}O_3$ $(M + H)^+$ requires 269.2116; found 269.2122. APCI-MS: *m*/*z* (relative intensity): 269.2 ($(M + H)^+$, 100%), 213.2 (11), 180.1 (11), 157.1 (17), 124.1 (30).

(2*R,3*S**,5*S**,6*R**)-Ethyl 2-ethyl-tetrahydro-6-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (3k)**

Colourless oil (118 mg, 39%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.96 (t, J = 7.2 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 1.43 (s, 3 H), 1.46–1.57 (m, 1 H), 1.58–1.68 (m, 1 H), 2.01 (ddd, J = 12.8, 12.4 and 12.0 Hz, 1 H), 2.08 (ddd, J = 12.8, 4.4 and 4.0 Hz, 1 H), 2.28 (ddd, J = 12.4, 10.0 and 4.0 Hz, 1 H), 2.56 (ddd, J = 12.0, 10.0 and 4.4 Hz, 1 H), 3.64 (ddd, J = 10.0, 7.2, 3.2 Hz, 1 H), 4.16 (q, J = 7.2 Hz, 2 H), 4.28 (d, J = 10.0 Hz, 1 H), 4.62 (brs, 1 H), 4.66 (brs, 1 H), 7.24–7.30 (m, 5 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 9.7, 14.4, 21.6, 27.2, 34.2, 47.5, 49.8, 60.6, 79.7, 83.9, 113.0, 127.5, 127.8, 128.2, 141.1, 145.3, 174.2; IR (KBr, neat): 2963, 2929, 2855, 1724, 1644, 1447, 1379, 1177, 1102, 1061, 1027, 747, 697 cm^{-1}. HRMS (APCI) cald for $C_{19}H_{26}O_3$ $(M + H)^+$ requires 303.1960; found 303.1962. APCI-MS: *m*/*z* (relative intensity): 303.2 ($(M + H)^+$, 15%), 257.2 (9), 211.2 (14), 171.1 (16), 125.1 (9), 124.1 (100), 97.1 (5), 79.0 (11).

(2*R,3*S**,5*S**,6*R**)-Ethyl 2-ethyl-tetrahydro-5-(prop-1-en-2-yl)-6-*p*-tolyl-2*H*-pyran-3-carboxylate (3l)**

Colourless oil (108 mg, 34%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.94 (t, J = 7.2 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 1.45 (s, 3 H), 1.47–1.55 (m, 1 H), 1.56–1.65 (m, 1 H), 2.00 (ddd, J = 12.8, 12.0 and 12.0 Hz, 1 H), 2.07 (ddd, J = 12.8, 4.0 and 4.0 Hz, 1 H), 2.31 (s, 3 H), 2.32 (ddd, J = 12.0, 10.4 and 4.0 Hz, 1 H), 2.54 (ddd, J = 12.0, 10.0 and 4.0 Hz, 1 H), 3.62 (ddd, J = 10.4, 7.2 and 3.2 Hz, 1 H), 4.15 (q, J = 7.2 Hz, 2 H), 4.25 (d, J = 10.0 Hz, 1 H), 4.63 (brs, 1 H), 4.66 (brs, 1 H), 7.09 (d, J = 7.6 Hz, 2 H), 7.18 (d, J = 8.0 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 9.7, 14.4, 21.4, 21.5, 27.1, 34.3, 47.5, 49.5, 60.6, 79.7, 83.6, 112.8, 127.4, 128.9, 137.4, 138.1, 145.5, 174.2; IR (KBr, neat): 2965, 2935, 2862, 1730, 1645, 1451, 1375, 1173, 1108, 1067, 967, 891, 815, 768 cm^{-1}. HRMS (APCI) cald for $C_{20}H_{28}O_3$ $(M + H)^+$ requires 317.2116; found 317.2128. APCI-MS: *m*/*z* (relative intensity): 317.2 ($(M + H)^+$, 29%), 299.2 (18), 271.2 (16), 253.2 (11), 225.2 (18), 171.1 (16), 151.1 (5), 124.1 (100), 123.1 (22), 82.0 (40).

(2*R,3*S**,5*S**,6*R**)-Ethyl 6-(4-(methoxycarbonyl)phenyl)-2-ethyl-tetrahydro-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (3m)**

Colourless oil (133 mg, 37%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.96 (t, J = 7.2 Hz, 3 H), 1.28 (t, J = 7.2 Hz, 3 H), 1.43 (s, 3 H), 1.48–1.58 (m, 1 H), 1.60–1.69 (m, 1 H), 2.02 (ddd, J = 13.2, 12.8 and 12.0 Hz, 1 H), 2.09 (ddd, J = 13.2, 4.0 and 4.0 Hz, 1 H), 2.24 (ddd, J = 12.8, 10.4 and 4.0 Hz, 1 H), 2.57 (ddd, J = 12.0, 10.0 and 4.0 Hz, 1 H), 3.65 (ddd, J = 10.4, 7.2 and 2.8 Hz, 1 H), 3.90 (s, 3 H), 4.16 (q, J = 7.2 Hz, 2 H), 4.33 (d, J = 10.0 Hz, 1 H), 4.60 (brs, 1 H), 4.67 (brs, 1 H), 7.36 (d, J = 8.4 Hz, 2 H), 7.97(d, J = 8.8 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 9.6, 14.4, 21.7, 27.1, 34.0, 47.4, 50.0, 52.2, 60.7, 76.7, 83.3, 113.4, 127.4, 129.5(2C), 144.7, 146.2, 167.2, 174.0; IR (KBr, neat): 2935, 2857, 1726, 1645, 1437, 1375, 1278, 1176, 1108, 1069, 895, 760 cm^{-1}. HRMS (APCI) cald for $C_{21}H_{28}O_5$ (M + H)$^+$ requires 361.2015; found 361.2023. APCI-MS: *m*/*z* (relative intensity): 361.2 ((M + H)$^+$, 1%), 178.1 (4), 125.1 (11), 124.1 (100), 123.1 (20), 85.0 (4), 82.0 (34).

(2*R,3*S**,5*S**,6*S**)-Ethyl 2-ethyl-tetrahydro-5-(prop-1-en-2-yl)-6-propyl-2*H*-pyran-3-carboxylate (3n)**

Colourless oil (113 mg, 42%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.89 (t, J = 6.8 Hz, 3 H), 0.98 (t, J = 7.2 Hz, 3 H), 1.25 (t, J = 7.2 Hz, 3 H), 1.28–1.58 (m, 6 H), 1.67 (s, 3 H), 1.82 (ddd, J = 12.8, 12.4 and 12.0 Hz, 1 H), 1.92 (ddd, J = 12.8, 4.0 and 3.6 Hz, 1 H), 1.98 (ddd, J = 12.4, 10.0 and 3.6 Hz, 1 H), 2.34 (ddd, J = 12.0, 10.0 and 4.0 Hz, 1 H), 3.28 (dt, J = 10.0 and 7.2 Hz, 1 H), 3.36 (dt, J = 10.0 and 6.8 Hz, 1 H), 4.12 (q, J = 7.2 Hz, 2 H), 4.75 (brs, 1 H), 4.77 (brs, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 10.2, 14.1, 14.4, 19.0, 20.2, 27.5, 34.0, 35.6, 48.3, 49.1, 60.5, 79.4, 79.6, 112.7, 146.1, 174.3; IR (KBr, neat): 2960, 2937, 2873, 1732, 1644, 1454, 1375, 1175, 1116, 1038, 1011, 893, 859 cm^{-1}. HRMS (APCI) cald for $C_{16}H_{28}O_3$ (M + H)$^+$ requires 269.2116; found 269.2108. APCI-MS: *m*/*z* (relative intensity): 269.2 ((M + H)$^+$, 61%), 223.2 (16), 195.2 (9), 178.1 (5), 125.1 (8), 124.1 (100), 123.1 (18), 101.1 (1), 82.0 (35).

(2*R,3*S**,5*S**,6*S**)-Ethyl 2-ethyl-6-hexyl-tetrahydro-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (3o)**

Colourless oil (127 mg, 41%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.87 (t, J = 6.4 Hz, 3 H), 0.98 (t, J = 7.2 Hz, 3 H), 1.25 (t, J = 7.2 Hz, 3 H), 1.25–1.35 (m, 9 H), 1.37–1.46 (m, 1 H), 1.47–1.57 (m, 2 H), 1.66 (s, 3 H), 1.82 (ddd, J = 12.4, 12.4 and 12.4 Hz, 1 H), 1.92 (ddd, J = 12.4, 4.0 and 3.6 Hz, 1 H), 1.98 (ddd, J = 12.4, 10.0 and 3.6 Hz, 1 H), 2.33 (ddd, J = 12.4, 10.0 and 4.0 Hz, 1 H), 3.27 (dt, J = 10.0 and 8.8 Hz, 1 H), 3.35 (dt, J = 10.0 and 6.8 Hz, 1 H), 4.12 (q, J = 7.2 Hz, 2 H), 4.75 (brs, 1 H), 4.77 (brs, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 10.2, 14.3, 14.4, 20.2, 22.8, 25.7, 27.4, 29.3, 32.1, 33.5, 34.0, 48.3, 49.1, 60.5, 79.6, 79.7, 112.7, 146.1, 174.3; IR (KBr, neat): 2930, 2857, 1732, 1640, 1454, 1375, 1173, 1117, 1038, 892 cm^{-1}. HRMS (APCI) cald for $C_{19}H_{34}O_3$ (M + H)$^+$ requires 311.2586; found 311.2587. APCI-MS: *m*/*z* (relative intensity): 310.6 (M$^+$, 100), 255.6 (4), 254.6 (23), 212.7 (4), 179.7 (11), 176.7 (15), 170.7 (8), 123.8 (81).

(2*R,3*S**,5*S**,6*S**)-Ethyl 2-ethyl-tetrahydro-6-isobutyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (3p)**

Colourless oil (124 mg, 44%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.86 (d, J = 6.8 Hz, 3 H), 0.90 (d, J = 6.8 Hz, 3 H), 0.97 (t, J = 7.6 Hz, 3 H), 1.17–1.58 (m, 4 H), 1.25 (t, J = 7.2 Hz, 3 H), 1.66 (s, 3 H), 1.78–2.00 (m, 4 H), 2.33 (ddd, J = 12.0, 10.0 and 4.0 Hz, 1 H), 3.32–3.38 (m, 2 H), 4.12 (q, J = 7.2 Hz, 2 H), 4.75 (brs, 1 H), 4.76 (brs, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 10.4, 14.4, 20.1, 21.4, 24.1, 24.3, 27.4, 34.1, 42.5, 48.4, 49.4, 60.5, 77.8, 79.8, 112.8, 146.1, 174.3; IR (KBr, neat): 2956, 2928, 2870, 1732, 1644, 1462, 1374, 1175, 1153, 1117, 1070, 1016, 892, 856 cm^{-1}. HRMS (APCI) cald for $C_{17}H_{30}O_3$ (M + H)$^+$ requires 283.2273; found 283.2275. APCI-MS: *m*/*z* (relative intensity): 282.6 (M$^+$, 33%), 177.7 (4), 124.8 (8), 123.8 (100), 122.8 (36), 81.9 (10).

(2*R,3*R**,5*S**,6*R**)-Ethyl tetrahydro-2-methyl-6-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (4a)**

Colourless oil (110 mg, 38%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.32 (d, J = 6.4 Hz, 3 H), 1.33 (t, J = 7.2 Hz, 3 H), 1.42 (s, 3 H), 1.90 (ddd, J = 13.6, 12.8 and 5.2 Hz, 1 H), 2.14 (ddd, J = 13.6, 4.0 and 4.0 Hz, 1 H), 2.60–2.67 (m, 1 H), 3.01 (ddd, J = 12.8, 12.4 and 4.0 Hz, 1 H), 3.82–3.89 (m, 1 H), 4.14–4.28 (m, 3 H), 4.63 (brs, 1 H), 4.67 (brs, 1 H), 7.22–7.25 (m, 1 H), 7.26–7.31 (m, 2 H), 7.32–7.36 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.6, 20.0, 21.8, 32.7, 44.4, 45.2, 60.3, 74.3, 85.0, 112.6, 127.7, 127.8, 128.2, 141.3, 145.8, 173.0; IR (KBr, neat): 2979, 2934, 1732, 1644, 1449, 1383, 1174, 1160, 1073, 758, 700 cm^{-1}. HRMS (APCI) cald for $C_{18}H_{24}O_3$ (M + H)$^+$ requires 289.1803; found 289.1799. APCI-MS: *m*/*z* (relative intensity): 289.2 ((M + H)$^+$, 77%), 225.1 (36), 197.1 (64), 159.1 (26), 157.1 (42), 124.1 (100), 123.1 (31), 99.0 (9), 82.0 (58).

(2*R,3*R**,5*S**,6*R**)-Ethyl tetrahydro-2-methyl-5-(prop-1-en-2-yl)-6-*p*-tolyl-2*H*-pyran-3-carboxylate (4b)**

Colourless oil (103 mg, 34%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.32 (d, J = 6.8 Hz, 3 H), 1.33 (t, J = 7.2 Hz, 3 H), 1.44 (s, 3 H), 1.90 (ddd, J = 13.6, 13.2 and 4.8 Hz, 1 H), 2.14 (ddd, J = 13.6, 4.0 and 4.0 Hz, 1 H), 2.30 (s, 3 H), 2.59–2.66 (m, 1 H), 3.02 (ddd, J = 13.2, 10.4 and 4.0 Hz, 1 H), 3.80–3.89 (m, 1 H), 4.15–4.28 (m, 3 H), 4.64 (brs, 1 H), 4.67 (brs, 1 H), 7.09 (d, J = 7.6 Hz, 2 H), 7.23 (d, J = 8.0 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.6, 20.1, 21.4, 21.7, 32.8, 44.5, 45.0, 60.3, 74.3, 84.8, 112.5, 127.6, 129.0, 137.4, 138.4, 146.1, 173.1; IR (KBr, neat): 2978, 2927, 2855, 1733, 1644, 1380, 1174, 1157, 1075, 810 cm^{-1}. HRMS (APCI) cald for $C_{19}H_{26}O_3$ (M + H)$^+$ requires 303.1960; found 303.1958. APCI-MS: *m*/*z* (relative intensity): 303.2 ((M + H)$^+$, 52%), 285.2 (51), 239.1 (20), 211.1 (31), 184.1 (36), 173.1 (28), 150.1 (15), 124.1 (100).

(2*R,3*R**,5*S**,6*R**)-Ethyl 6-(4-bromophenyl)-tetrahydro-2-methyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (4c)**

Colourless oil (110 mg, 30%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.31 (d, J = 5.6 Hz, 3 H), 1.33 (t, J = 7.2 Hz, 3 H), 1.44 (s, 3

H), 1.90 (ddd, J = 13.6, 12.8 and 5.2 Hz, 1 H), 2.13 (ddd, J = 13.6, 4.0 and 3.6 Hz, 1 H), 2.60–2.67 (m, 1 H), 2.95 (ddd, J = 12.8, 12.8 and 4.0 Hz, 1 H), 3.81–3.88 (m, 1 H), 4.12–4.28 (m, 3 H), 4.62 (brs, 1 H), 4.68 (brs, 1 H), 7.22 (d, J = 8.4 Hz, 2 H), 7.41 (d, J = 8.4 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.6, 20.0, 21.8, 32.6, 44.2, 45.2, 60.3, 74.3, 84.1, 113.0, 121.7, 129.4, 131.4, 140.5, 145.4, 172.9; IR (KBr, neat): 2979, 2934, 2855, 1732, 1644, 1446, 1383, 1174, 1157, 1074, 921, 813 cm^{-1}. HRMS (APCI) cald for $C_{18}H_{23}BrO_3$ $(M + H)^+$ requires 367.0909; found 367.0911 (^{79}Br). APCI-MS: m/z (relative intensity): 369.1 ($(M + H)^+$, 19%, ^{81}Br), 367.1 ($(M + H)^+$, 20, ^{79}Br), 351.1 (9), 349.1 (9), 275.1 (6), 202.2 (13), 201.2 (100), 184.1 (9), 124.1 (75).

(2*R,3*R**,5*S**,6*R**)-Ethyl 6-(4-chlorophenyl)-tetrahydro-2-methyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (4d)**

Colourless oil (94 mg, 29%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.32 (d, J = 6.0 Hz, 3 H), 1.33 (t, J = 7.2 Hz, 3 H), 1.43 (s, 3 H), 1.89 (ddd, J = 13.2, 12.8 and 4.8 Hz, 1 H), 2.14 (ddd, J = 13.2, 4.0 and 3.6 Hz, 1 H), 2.60–2.68 (m, 1 H), 2.95 (ddd, J = 12.8, 12.8 and 3.6 Hz, 1 H), 3.80–3.89 (m, 1 H), 4.16–4.29 (m, 3 H), 4.62 (brs, 1 H), 4.69 (brs, 1 H), 7.26 (d, J = 8.8 Hz, 2 H), 7.41 (d, J = 8.8 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.6, 20.0, 21.8, 32.6, 44.2, 45.3, 60.3, 74.3, 84.1, 113.0, 128.4, 129.0, 133.4, 140.0, 145.5, 172.9; IR (KBr, neat): 2978, 2933, 2857, 1731, 1644, 1447, 1382, 1174, 1157, 1076, 894, 815 cm^{-1}. HRMS (APCI) cald for $C_{18}H_{23}ClO_3$ $(M + H)^+$ requires 323.1414; found 323.1405 (^{35}Cl). APCI-MS: m/z (relative intensity): 325.0 ($(M + H)^+$, 3%, ^{37}Cl), 323.0 ($(M + H)^+$, 7, ^{35}Cl), 259.0 (4), 231 (9), 184.0 (7), 157 (13), 124.0 (100), 123.0 (17), 85.0 (5), 82.0 (29).

(2*R,3*R**,5*S**,6*R**)-Ethyl 6-(4-fluorophenyl)-tetrahydro-2-methyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (4e)**

Colourless oil (107 mg, 35%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.32 (d, J = 6.4 Hz, 3 H), 1.33 (t, J = 7.2 Hz, 3 H), 1.43 (s, 3 H), 1.89 (ddd, J = 13.6, 12.8 and 4.6 Hz, 1 H), 2.14 (ddd, J = 13.6, 4.0 and 3.6 Hz, 1 H), 2.60–2.67 (m, 1 H), 2.97 (ddd, J = 12.8, 10.4 and 4.0 Hz, 1 H), 3.82–3.89 (m, 1 H), 4.18–4.28 (m, 3 H), 4.63 (brs, 1 H), 4.69 (brs, 1 H), 6.98 (t, J = 8.8 Hz, 2 H), 7.30–7.34 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.6, 20.0, 21.8, 32.6, 44.3, 45.4, 60.3, 74.3, 84.1, 112.8, 115.1 (d, J = 20.6 Hz), 129.3 (d, J = 9.7 Hz), 137.3, 145.7, 162.5 (d, J = 244.1 Hz), 173.0; ^{19}F NMR (376 MHz, $CDCl_3$–C_6F_6): δ −219.09–(−219.01) (m, 1F); IR (KBr, neat): 2979, 2934, 2858, 1732, 1644, 1448, 1382, 1176, 1157, 1075, 832 cm^{-1}. HRMS (APCI) cald for $C_{18}H_{23}FO_3$ $(M + H)^+$ requires 307.1709; found 307.1702. APCI-MS: m/z (relative intensity): 307.0 ($(M + H)^+$, 28%), 289.0 (35), 243.0 (18), 215.0 (40), 177.0 (26), 157.0 (30), 124.0 (100), 123.0 (16), 82.0 (26).

(2*R,3*R**,5*S**,6*R**)-Ethyl tetrahydro-2-methyl-6-(4-nitrophenyl)-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (4f)**

Colourless oil (90 mg, 27%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.33 (d, J = 5.6 Hz, 3 H), 1.34 (t, J = 7.2 Hz, 3 H), 1.46 (s, 3 H), 1.89 (ddd, J = 14.0, 12.8 and 5.2 Hz, 1 H), 2.16 (ddd, J = 14.0, 4.0 and 2.0 Hz, 1 H), 2.63–2.70 (m, 1 H), 2.95 (ddd, J = 12.8, 12.4 and 4.0 Hz, 1 H), 3.84–3.92 (m, 1 H), 4.17–4.28 (m, 2 H), 4.37 (d, J = 10.4 Hz, 1 H), 4.62 (brs, 1 H), 4.72 (brs, 1 H), 7.51 (d, J = 8.8 Hz, 2 H), 8.16 (d, J = 8.8 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.6, 19.9, 21.7, 32.4, 44.0, 45.6, 60.5, 74.3, 83.6, 113.6, 123.5, 128.5, 144.7, 147.6, 148.8, 172.8; IR (KBr, neat): 2979, 2935, 2858, 1728, 1643, 1520, 1447, 1345, 1174, 1077, 851, 752 cm^{-1}. HRMS (APCI) cald for $C_{18}H_{23}NO_5$ $(M + H)^+$ requires 334.1654; found 334.1666. APCI-MS: m/z (relative intensity): 334.2 ($(M + H)^+$, 1%), 250.0 (2), 180.1 (2), 136.1 (4), 125.1 (10), 124.1 (100), 123.1 (20), 82.0 (36).

(2*R,3*R**,5*S**,6*R**)-Ethyl 6-(4-(methoxycarbonyl)phenyl)-tetrahydro-2-methyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (4g)**

Colourless solid; M.P.: 100–102 °C (111 mg, 32%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.33 (t, J = 7.2 Hz, 3 H), 1.34 (d, J = 6.8 Hz, 3 H), 1.41 (s, 3 H), 1.92 (ddd, J = 14.0, 12.8 and 5.2 Hz, 1 H), 2.15 (ddd, J = 14.0, 4.0 and 2.0 Hz, 1 H), 2.63–2.70 (m, 1 H), 2.97 (ddd, J = 12.8, 10.0 and 4.0 Hz, 1 H), 3.81–3.88 (m, 1 H), 3.89 (s, 3 H), 4.16–4.28 (m, 2 H), 4.30 (d, J = 10.0 Hz, 1 H), 4.62 (brs, 1 H), 4.68 (brs, 1 H), 7.42 (d, J = 8.4 Hz, 2 H), 7.97 (d, J = 8.4 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.6, 19.9, 21.8, 32.5, 44.2, 45.4, 52.2, 60.4, 74.3, 84.4, 113.1, 127.6, 129.6 (2C), 145.2, 146.5, 167.2, 172.9; IR (KBr, neat): 2955, 2928, 2873, 1726, 1643, 1449, 1277, 1173, 1158, 1076, 772, 705 cm^{-1}. HRMS (APCI) cald for $C_{20}H_{26}O_5$ $(M + H)^+$ requires 347.1858; found 347.1868. APCI-MS: m/z (relative intensity): 347.2 ($(M + H)^+$, 5%), 315.2 (2), 297.2 (3), 184.1 (3), 157.1 (5), 150.1 (10), 124.1 (100), 123.1 (70), 85.0 (6).

(2*R,3*R**,5*S**,6*S**)-Ethyl tetrahydro-2-methyl-5-(prop-1-en-2-yl)-6-propyl-2*H*-pyran-3-carboxylate (4h)**

Colourless oil (104 mg, 41%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.97 (t, J = 7.6 Hz, 3 H), 1.27 (t, J = 7.2 Hz, 3 H), 1.28 (d, J = 6.0 Hz, 3 H), 1.30–1.42 (m, 2 H), 1.43–1.58 (m, 2 H), 1.67 (s, 3 H), 1.72 (ddd, J = 13.6, 12.8 and 5.2 Hz, 1 H), 1.98 (ddd, J = 13.6, 4.0 and 2.4 Hz, 1 H), 2.49–2.55 (m, 1 H), 2.63 (ddd, J = 12.8, 10.0 and 4.0 Hz, 1 H), 3.26 (dt, J = 10.0 and 6.0 Hz, 1 H), 3.62–3.70 (m, 1 H), 4.11–4.21 (m, 2 H), 4.77 (brs, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.1, 14.4, 18.8, 19.8, 20.2, 32.6, 35.6, 44.2, 44.3, 60.1, 73.9, 80.7, 112.4, 146.7, 173.0; IR (KBr, neat): 2960, 2936, 2872, 1735, 1648, 1382, 1173, 1115, 1084, 992, 892 cm^{-1}. HRMS (APCI) cald for $C_{15}H_{26}O_3$ $(M + H)^+$ requires 255.1960; found 255.1965. APCI-MS: m/z (relative intensity): 255.2 ($(M + H)^+$, 16%), 254.6 (97), 198.7 (4), 179.7 (13), 176.7 (19), 156.7 (100).

(2*R, 3*R**, 5*S**, 6*S**)-Ethyl 6-hexyl-tetrahydro-2-methyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (4i)**

Colourless oil (116 mg, 39%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.87 (t, J = 7.2 Hz, 3 H), 1.20–1.40 (m, 8 H), 1.27 (t, J = 7.2 Hz, 3 H), 1.28 (d, J = 6.0 Hz, 3 H), 1.45–1.53 (m, 2 H), 1.67 (s, 3 H), 1.72 (ddd, J = 12.8, 12.8 and 5.2 Hz, 1 H), 1.97 (ddd,

J = 12.8, 4.0 and 2.0 Hz, 1 H), 2.50–2.56 (m, 1 H), 2.63 (ddd, J = 12.8, 10.0 and 4.0 Hz, 1 H), 3.25 (dt, J = 10.0 and 8.4 Hz, 1 H), 3.62–3.69 (m, 1 H), 4.11–4.21 (m, 2 H), 4.77 (brs, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.3. 14.5, 19.9, 20.4, 22.9, 25.8, 29.5, 32.1, 32.6, 33.6, 44.3, 44.4, 60.2, 74.0, 81.1, 112.5, 146.8, 173.1; IR (KBr, neat): 2927, 2856, 1735, 1640, 1445, 1380, 1173, 1113, 1083, 892 cm^{-1}. HRMS (APCI) cald for $C_{18}H_{32}O_3$ $(M + H)^+$ requires 297.2429; found 297.2424. APCI-MS: m/z (relative intensity): 297.2 ($(M + H)^+$, 81%), 279.2 (4), 158.1 (7), 157.1 (81), 124.1 (100), 123.1 (58), 101.1 (7).

(2*R,3*R**,5*S**,6*S**)-Ethyl tetrahydro-6-isobutyl-2-methyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (4j)**

Colourless oil (115 mg, 43%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.84 (d, J = 6.4 Hz, 3 H), 0.88 (d, J = 6.4 Hz, 3 H), 1.19 (ddd, J = 10.4, 8.0 and 6.0 Hz, 1 H), 1.27 (t, J = 6.8 Hz, 3 H), 1.28 (d, J = 6.4 Hz, 3 H), 1.39 (ddd, J = 10.4, 6.4 and 4.0 Hz, 1 H), 1.67 (s, 3 H), 1.73 (ddd, J = 13.6, 13.2 and 5.2 Hz, 1 H), 1.83–1.91 (m, 1 H), 1.98 (ddd, J = 13.6, 4.0 and 2.0 Hz, 1 H), 2.49–2.55 (m, 1 H), 2.60 (ddd, J = 13.2, 10.8 and 4.0 Hz, 1 H), 3.32 (dt, J = 10.8 and 8.4 Hz, 1 H), 3.62–3.69 (m, 1 H), 4.11–4.21 (m, 2 H), 4.77 (brs, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.5, 19.9, 20.2, 21.6, 24.0, 24.1, 32.7, 42.5, 44.3, 44.8, 60.2, 74.0, 79.0, 112.5, 146.8, 173.1; IR (KBr, neat): 2954, 2928, 2868, 1736, 1644, 1448, 1383, 1173, 1116, 1082, 1026, 892 cm^{-1}. HRMS (APCI) cald for $C_{16}H_{28}O_3$ $(M + H)^+$ requires 269.2116; found 269.2112. APCI-MS: m/z (relative intensity): 269.1 ($(M + H)^+$, 42%), 251.1 (6), 177.1 (7), 158.0 (10), 157.0 (100), 124.0 (12), 111.0 (24).

(2*R,3*R**,5*S**,6*R**)-Ethyl 2-ethyl-tetrahydro-6-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (4k)**

Colourless oil (106 mg, 35%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.97 (t, J = 7.6 Hz, 3 H), 1.32 (t, J = 7.2 Hz, 3 H), 1.43 (s, 3 H), 1.57–1.74 (m, 2 H), 1.88 (ddd, J = 13.6, 13.2 and 5.6 Hz, 1 H), 2.16 (ddd, J = 13.6, 4.0 and 2.0 Hz, 1 H), 2.70–2.76 (m, 1 H), 3.03 (ddd, J = 13.2, 10.4 and 4.0 Hz, 1 H), 3.55 (dt, J = 6.8 and 2.8 Hz, 1 H), 4.16–4.26 (m, 3 H), 4.63 (brs, 1 H), 4.67 (brs, 1 H), 7.20–7.31 (m, 3 H), 7.33–7.35 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 10.8, 14.6, 21.8, 27.1, 32.8, 42.5, 45.5, 60.3, 80.4, 85.1, 112.6, 127.7, 128.0, 128.2, 141.5, 146.0, 173.0; IR (KBr, neat): 2965, 2935, 2856, 1733, 1644, 1453, 1376, 1173, 1071, 892, 756, 699 cm^{-1}. HRMS (APCI) cald for $C_{19}H_{26}O_3$ $(M + H)^+$ requires 303.1960; found 303.1969. APCI-MS: m/z (relative intensity): 303.2 ($(M + H)^+$, 11%), 285.2 (8), 257.2 (6), 239.2 (7), 211.2 (16), 171.1 (5), 159.1 (7), 125.1 (9), 124.1 (100), 82.0 (27).

(2*R,3*R**,5*S**,6*R**)-Ethyl 2-ethyl-tetrahydro-5-(prop-1-en-2-yl)-6-*p*-tolyl-2*H*-pyran-3-carboxylate (4l)**

Colourless oil (114 mg, 36%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.96 (t, J = 7.6 Hz, 3 H), 1.32 (t, J = 7.2 Hz, 3 H), 1.45 (s, 3 H), 1.57–1.72 (m, 2 H), 1.86 (ddd, J = 13.6, 13.2 and 5.2 Hz, 1 H), 2.15 (ddd, J = 13.6, 4.0 and 2.0 Hz, 1 H), 2.30 (s, 3 H), 2.68–2.74 (m, 1 H), 3.03 (ddd, J = 13.2, 10.8 and 4.0 Hz, 1 H), 3.54 (dt, J = 7.2 and 4.4 Hz, 1 H), 4.14–4.26 (m, 3 H), 4.64 (brs, 1 H), 4.67 (brs, 1 H), 7.09 (d, J = 7.6 Hz, 2 H), 7.22 (d, J = 8.0 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 10.8, 14.6, 21.4, 21.7, 27.1, 32.9, 42.6, 45.3, 60.2, 80.4, 84.8, 112.5, 127.6, 128.9, 137.3, 138.5, 146.2, 173.1; IR (KBr, neat): 2961, 2935, 2956, 1733, 1644, 1449, 1376, 1174, 1160, 1074, 890, 813 cm^{-1}. HRMS (APCI) cald for $C_{20}H_{28}O_3$ $(M + H)^+$ requires 317.2116; found 317.2122. APCI-MS: m/z (relative intensity): 317.2 ($(M + H)^+$, 22%), 299.2 (25), 269.2 (8), 253.2 (14), 225.2 (21), 198.2 (18), 171.2 (25), 125.1 (11), 124.1 (100).

(2*R,3*R**,5*S**,6*R**)-Ethyl 6-(4-(methoxycarbonyl)phenyl)-2-ethyl-tetrahydro-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (4m)**

Colourless oil (112 mg, 31%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.97 (t, J = 7.6 Hz, 3 H), 1.33 (t, J = 7.2 Hz, 3 H), 1.42 (s, 3 H), 1.57–1.74 (m, 2 H), 1.89 (ddd, J = 12.8, 12.8 and 5.2 Hz, 1 H), 2.16 (ddd, J = 12.8, 4.0 and 2.0 Hz, 1 H), 2.71–2.77 (m, 1 H), 2.98 (ddd, J = 12.8, 10.4 and 4.0 Hz, 1 H), 3.56 (dt, J = 9.6 and 3.2 Hz, 1 H), 3.89 (s, 3 H), 4.17–4.30 (m, 2 H), 4.28 (d, J = 10.4 Hz, 1 H), 4.62 (brs, 1 H), 4.68 (brs, 1 H), 7.42 (d, J = 8.0 Hz, 2 H), 7.97 (d, J = 8.4 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 10.7, 14.6, 21.8, 27.1, 32.7, 42.4, 45.7, 52.2, 60.3, 80.3, 84.5, 113.0, 127.7, 129.3, 129.5, 145.4, 146.7, 167.3, 172.9; IR (KBr, neat): 2935, 2851, 1726, 1644, 1436, 1376, 1278, 1176, 1112, 1078, 859, 767 cm^{-1}. HRMS (APCI) cald for $C_{21}H_{28}O_5$ $(M + H)^+$ requires 361.2015; found 361.2012. APCI-MS: m/z (relative intensity): 361.2 ($(M + H)^+$, 5%), 303.2 (23), 271.3 (14), 211.2 (15), 178.1 (30), 155.1 (23), 124.1 (100), 91.1 (23), 84.1 (42).

(2*R,3*R**,5*S**,6*S**)-Ethyl 2-ethyl-tetrahydro-5-(prop-1-en-2-yl)-6-propyl-2*H*-pyran-3-carboxylate (4n)**

Colourless oil (123 mg, 46%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.88 (t, J = 7.2 Hz, 3 H), 0.99 (t, J = 7.2 Hz, 3 H), 1.26 (t, J = 7.2 Hz, 3 H), 1.29–1.51 (m, 4 H), 1.52–1.64 (m, 2 H), 1.67 (s, 3 H), 1.71 (ddd, J = 14.0, 12.4 and 5.2 Hz, 1 H), 1.98 (ddd, J = 14.0, 4.0 and 2.0 Hz, 1 H), 2.56–2.62 (m, 1 H), 2.64 (ddd, J = 12.4, 10.0 and 4.0 Hz, 1 H), 3.23 (dt, J = 10.0 and 6.8 Hz, 1 H), 3.35 (ddd, J = 8.4, 5.6 and 3.2 Hz, 1 H), 4.08–4.20 (m, 2 H), 4.77 (brs, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 11.0, 14.1, 14.5, 19.0, 20.4, 27.2, 32.7, 35.7, 43.0, 44.9, 60.1, 80.1, 80.9, 112.4, 146.9, 173.1; IR (KBr, neat): 2960, 2936, 2874, 1736, 1644, 1456, 1379, 1174, 1115, 1084, 1033, 892 cm^{-1}. HRMS (APCI) cald for $C_{16}H_{28}O_3$ $(M + H)^+$ requires 269.2116; found 269.2125. APCI-MS: m/z (relative intensity): 269.2 ($(M + H)^+$, 37%), 251.2 (6), 172.1 (10), 171.1 (100), 125.1 (5), 124.1 (44), 97.1 (13).

(2*R,3*R**,5*S**,6*S**)-Ethyl 2-ethyl-6-hexyl-tetrahydro-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (4o)**

Colourless oil (121 mg, 39%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.87 (t, J = 6.8 Hz, 3 H), 0.99 (t, J = 7.6 Hz, 3 H), 1.24–1.40 (m, 10 H), 1.26 (t, J = 7.2 Hz, 3 H), 1.47–1.54 (m, 1 H), 1.55–1.64 (m, 1 H), 1.67 (s, 3 H), 1.71 (ddd, J = 13.2, 12.8 and

5.2 Hz, 1 H), 1.98 (ddd, J = 13.2, 4.0 and 1.6 Hz, 1 H), 2.55–2.61 (m, 1 H), 2.64 (ddd, J = 12.8, 10.4 and 4.0 Hz, 1 H), 3.22 (dt, J = 10.4 and 8.4 Hz, 1 H), 3.34 (ddd, J = 8.4, 5.6 and 3.2 Hz, 1 H), 4.09–4.20 (m, 2 H), 4.77 (brs, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 10.9, 14.2, 14.4, 20.3, 22.8, 25.8, 27.1, 29.4, 32.1, 32.7, 33.6, 42.9, 44.8, 60.0, 80.1, 81.1, 112.3, 146.8, 173.0; IR (KBr, neat): 2930, 2857, 1736, 1644, 1457, 1378, 1173, 1157, 1085, 1032, 892 cm^{-1}. HRMS (APCI) cald for $C_{19}H_{34}O_3$ (M + H)$^+$ requires 311.2586; found 311.2588. APCI-MS: m/z (relative intensity): 311.3 ((M + H)$^+$, 29%), 293.3 (4), 219.2 (4), 172.1 (6), 171.1 (65), 125.1 (8), 124.1 (100).

(2*R,3*R**,5*S**,6*S**)-Ethyl 2-ethyl-tetrahydro-6-isobutyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (4p)**

Colourless oil (113 mg, 40%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.85 (d, J = 6.8 Hz, 3 H), 0.88 (d, J = 6.8 Hz, 3 H), 0.99 (t, J = 7.2 Hz, 3 H), 1.19 (ddd, J = 10.8, 8.8 and 8.4 Hz, 1 H), 1.26 (t, J = 7.2 Hz, 3 H), 1.42 (ddd, J = 10.4, 6.4 and 4.0 Hz, 1 H), 1.50–1.64 (m, 2 H), 1.66 (s, 3 H), 1.73 (ddd, J = 12.8, 12.8 and 4.0 Hz, 1 H), 1.85–1.94 (m, 1 H), 1.98 (ddd, J = 12.8, 4.0 and 2.0 Hz, 1 H), 2.55–2.61 (m, 1 H), 2.62 (ddd, J = 12.8, 10.0 and 4.0 Hz, 1 H), 3.27–3.37 (m, 2 H), 4.08–4.20 (m, 2 H), 4.77 (brs, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 11.1, 14.5, 20.2, 21.4, 24.0, 24.1, 27.1, 32.7, 42.5, 43.0, 45.2, 60.1, 79.1, 80.2, 112.5, 146.7, 173.1; IR (KBr, neat): 2956, 2934, 2870, 1735, 1643, 1465, 1382, 1173, 1116, 1084, 1015, 891, 853 cm^{-1}. HRMS (APCI) cald for $C_{17}H_{30}O_3$ (M + H)$^+$ requires 283.2273; found 283.2280. APCI-MS: m/z (relative intensity): 283.2 ((M + H)$^+$, 11%), 282.6 (63), 170.7 (17), 124.8 (8), 123.8 (100), 122.8 (56), 100.9 (7), 81.9 (14).

(2*S,3*S**,5*S**,6*R**)-Ethyl tetrahydro-2,6-diphenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (11a)**

Colourless oil (280 mg, 80%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.01 (t, J = 6.8 Hz, 3 H), 1.48 (s, 3 H), 2.17–2.23 (m, 2 H), 2.48 (ddd, J = 10.4, 10.0 and 3.2 Hz, 1 H), 2.87 (ddd, J = 10.0, 9.6 and 2.4 Hz, 1 H), 3.94 (q, J = 6.8 Hz, 2 H), 4.49 (d, J = 10.0 Hz, 1 H), 4.69–4.73 (m, 3 H), 7.23–7.32 (m, 4 H), 7.33–7.40 (m, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.1, 21.7, 34.2, 49.7, 50.5, 60.4, 81.8, 84.6, 113.2, 127.2, 127.4, 127.9, 128.2 (2C), 128.4, 140.2, 140.6, 144.9, 173.1; IR (KBr, neat): 2978, 2934, 2865, 1728, 1644, 1452, 1373, 1174, 1089, 1064, 755, 699 cm^{-1}. HRMS (APCI) cald for $C_{23}H_{26}O_3$ (M + H)$^+$ requires 351.1960; found 351.1962. APCI-MS: m/z (relative intensity): 351.2 ((M + H)$^+$, 6%), 335.1 (8), 243.1 (12), 212.1 (19), 177.1 (11), 136.1 (23), 119.1 (100).

(2*S,3*S**,5*S**,6*R**)-Ethyl tetrahydro-2-phenyl-5-(prop-1-en-2-yl)-6-*p*-tolyl-2*H*-pyran-3-carboxylate (11b)**

Colourless oil (255 mg, 70%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.00 (t, J = 7.2 Hz, 3 H), 1.50 (s, 3 H), 2.16–2.21 (m, 2 H), 2.29 (s, 3 H), 2.48 (ddd, J = 9.6, 9.6 and 2.4 Hz, 1 H), 2.84 (ddd, J = 9.6, 9.6 and 2.8 Hz, 1 H), 3.93 (q, J = 7.2 Hz, 2 H), 4.45 (d, J = 9.6 Hz, 1 H), 4.69–4.72 (m, 3 H), 7.08 (d, J = 7.6 Hz, 2 H), 7.22–7.30 (m, 5 H), 7.38 (d, J = 7.6 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.0, 21.3, 21.6, 34.2, 49.5, 50.5, 60.4, 81.8, 84.3, 113.1, 127.2, 127.4, 128.1, 128.3, 128.9, 137.5, 137.6, 140.3, 145.1, 173.2; IR (KBr, neat): 2978, 2930, 2865, 1728, 1644, 1452, 1373, 1173, 1062, 892, 768 cm^{-1}. HRMS (APCI) cald for $C_{24}H_{28}O_3$ (M + H)$^+$ requires 365.2116; found 365.2112. APCI-MS: m/z (relative intensity): 365.2 ((M + H)$^+$, 10%), 243.1 (5), 202.1 (16), 125.1 (9), 124.1 (100).

(2*S,3*S**,5*S**,6*R**)-Ethyl tetrahydro-6-(4-methoxyphenyl)-2-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (11c)**

Colourless solid, M.P. 114–116 °C (281 mg, 74%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.00 (t, J = 7.2 Hz, 3 H), 1.49 (s, 3 H), 2.16–2.21 (m, 2 H), 2.47 (ddd, J = 10.0, 9.6 and 2.8 Hz, 1 H), 2.84 (ddd, J = 10.0, 9.6 and 3.2 Hz, 1 H), 3.75 (s, 3 H), 3.93 (q, J = 7.2 Hz, 2 H), 4.44 (d, J = 10.0 Hz, 1 H), 4.68–4.73 (m, 3 H), 6.82 (d, J = 7.8 Hz, 2 H), 7.20–7.31 (m, 5 H), 7.38 (d, J = 7.6 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.1, 21.7, 34.3, 49.7, 50.6, 55.3, 60.5, 81.9, 84.1, 113.1, 113.6, 127.3, 128.2, 128.4, 128.7, 133.0, 140.3, 145.2, 159.3, 173.2; IR (KBr, neat): 2936, 2868, 1727, 1643, 1454, 1372, 1174, 1059, 1039, 910, 768 cm^{-1}. HRMS (APCI) cald for $C_{24}H_{28}O_4$ (M + H)$^+$ requires 381.2066; found 381.2062. APCI-MS: m/z (relative intensity): 381.0 ((M + H)$^+$, 24%), 363.0 (5), 189.0 (6), 151.0 (14), 137.0 (91), 124.1 (100).

(2*S,3*S**,5*S**,6*R**)-Ethyl 6-(4-fluorophenyl)-tetrahydro-2-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (11d)**

Colourless oil (221 mg, 60%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.00 (t, J = 7.2 Hz, 3 H), 1.49 (s, 3 H), 2.17–2.21 (m, 2 H), 2.42 (ddd, J = 10.4, 10.0 and 2.4 Hz, 1 H), 2.85 (ddd, J = 10.0, 9.6 and 2.8 Hz, 1 H), 3.93 (q, J = 7.2 Hz, 2 H), 4.47 (d, J = 10.4 Hz, 1 H), 4.68–4.72 (m, 3 H), 6.98 (t, J = 8.4 Hz, 2 H), 7.23–7.34 (m, 5 H), 7.38 (d, J = 7.6 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.1, 21.7, 34.1, 50.0, 50.5, 60.5, 82.0, 83.8, 113.4, 115.0 (d, J = 21.4 Hz), 127.2, 128.4 (d, J = 10.7 Hz), 129.0, 129.1, 136.6, 140.1, 144.8, 162.5 (d, J = 243.2 Hz), 173.1; ^{19}F NMR (376 MHz, $CDCl_3/C_6F_6$): δ −219.01–(−218.94) (m, 1F); IR (KBr, neat): 2929, 2857, 1728, 1640, 1453, 1374, 1174, 1157, 1086, 1064, 836, 769 cm^{-1}. HRMS (APCI) cald for $C_{23}H_{25}FO_3$ (M + H)$^+$ requires 369.1866; found 369.1873. APCI-MS: m/z (relative intensity): 369.2 ((M + H)$^+$, 8%), 277.2 (4), 178.1 (4), 177.1 (14), 125.1 (8), 124.1 (100).

(2*S,3*S**,5*S**,6*R**)-Ethyl tetrahydro-6-(4-nitrophenyl)-2-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (11e)**

Colourless oil (237 mg, 60%); ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.01 (t, J = 6.8 Hz, 3 H), 1.52 (s, 3 H), 2.18–2.30 (m, 2 H), 2.40 (ddd, J = 10.0, 10.0 and 2.4 Hz, 1 H), 2.89 (ddd, J = 10.4, 10.0 and 2.4 Hz, 1 H), 3.95 (q, J = 6.8 Hz, 2 H), 4.61 (d, J = 10.0 Hz, 1 H), 4.68 (brs, 1 H), 4.74 (d, J = 10.0 Hz, 1 H), 4.76 (brs, 1 H), 7.26–7.41 (m, 5 H), 7.52 (d, J = 8.8 Hz, 2 H), 8.16 (J = 8.8 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.1, 21.6, 33.9, 50.1, 50.2, 60.7, 81.9, 83.3, 114.2, 123.5, 127.2, 128.2, 128.6 (2C), 139.6, 143.9, 147.6, 147.9, 172.9; IR (KBr, neat): 2978,

2927, 2855, 1729, 1606, 1522, 1347, 1176, 1070, 751, 699 cm^{-1}. HRMS (APCI) cald for $C_{23}H_{25}NO_5$ $(M + H)^+$ requires 396.1811; found 396.1815. APCI-MS: *m/z* (relative intensity): 396.2 ($(M + H)^+$, 1%), 390.4 (1), 177.1 (4), 125.1 (10), 124.1 (100), 120.1 (4).

(2*S,3*S**,5*S**,6*R**)-Ethyl 6-(4-(methoxycarbonyl)phenyl)-tetrahydro-2-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (11f)**

Colourless solid, M.P.: 118–120 °C (266 mg, 65%); ^1H NMR (400 MHz, $CDCl_3$): δ 1.01 (t, J = 7.2 Hz, 3 H), 1.48 (s, 3 H), 2.17–2.23 (m, 2 H), 2.44 (ddd, J = 10.0, 9.6 and 2.8 Hz, 1 H), 2.89 (ddd, J = 10.0, 9.6 and 3.2 Hz, 1 H), 3.89 (s, 3 H), 3.94 (q, J = 7.2 Hz, 2 H), 4.54 (d, J = 10.0 Hz, 1 H), 4.67 (brs, 1 H), 4.72 (brs, 1 H), 4.73 (d, J = 9.6 Hz, 1 H), 7.27–7.33 (m, 3 H), 7.39–7.43 (m, 4 H), 7.97 (d, J = 8.4 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.0, 21.6, 33.9, 49.9, 50.3, 52.0, 60.4, 81.7, 83.9, 113.5, 127.1, 127.3, 128.2, 128.3, 129.4, 129.6, 139.9, 144.2, 145.6, 166.9, 172.8; IR (KBr, neat): 2978, 2950, 2862, 1725, 1643, 1374, 1278, 1176, 1111, 1065, 897, 763 cm^{-1}. HRMS (APCI) cald for $C_{25}H_{28}O_5$ $(M + H)^+$ requires 409.2015; found 409.2025. APCI-MS: *m/z* (relative intensity): 408.3 (M^+, 1%), 177.7 (4), 124.8 (8), 123.8 (100), 122.8 (37), 81.9 (10).

(2*S,3*S**,5*S**,6*S**)-Ethyl 6-ethyl-tetrahydro-2-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (11g)**

Colourless oil (278 mg, 92%); ^1H NMR (400 MHz, $CDCl_3$): δ 0.93 (t, J = 7.2 Hz, 3 H), 0.99 (t, J = 7.2 Hz, 3 H), 1.38–1.47 (m, 1 H), 1.61–1.71 (m, 1 H), 1.72 (s, 3 H), 1.99–2.05 (m, 2 H), 2.20 (ddd, J = 10.4, 10.0 and 5.6 Hz, 1 H), 2.67 (ddd, J = 10.0, 10.0 and 5.6 Hz, 1 H), 3.47 (ddd, J = 10.4, 10.0 and 7.6 Hz, 1 H), 3.91 (q, J = 7.2 Hz, 2 H), 4.51 (d, J = 10.0 Hz, 1 H), 4.82 (brs, 2 H), 7.24–7.36 (m, 5 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 9.8, 14.1, 20.2, 26.2, 34.0, 47.8, 50.4, 60.4, 81.2, 81.4, 112.9, 127.2, 128.1, 128.4, 140.8, 146.0, 173.5; IR (KBr, neat): 2961, 2931, 2875, 1730, 1644, 1374, 1344, 1174, 1067, 894, 754, 699 cm^{-1}. HRMS (APCI) cald for $C_{19}H_{26}O_3$ $(M + H)^+$ requires 303.1960; found 303.1954. APCI-MS: *m/z* (relative intensity): 303.2 ($(M + H)^+$, 21%), 301.2 (8), 285.2 (7), 245.2 (11), 211.2 (5), 177.1 (29), 125.1 (9), 124.1 (100).

(2*S,3*S**,5*S**,6*S**)-Ethyl tetrahydro-6-isobutyl-2-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (11h)**

Colourless oil (288 mg, 87%); ^1H NMR (400 MHz, $CDCl_3$): δ 0.84 (d, J = 6.4 Hz, 3 H), 0.85 (d, J = 7.2 Hz, 3 H), 1.00 (t, J = 7.2 Hz, 3 H), 1.26 (ddd, J = 14.0, 10.0 and 2.0 Hz, 1 H), 1.40 (ddd, J = 14.0, 10.0 and 4.0 Hz, 1 H), 1.71 (s, 3 H), 1.77–1.87 (m, 1 H), 1.99–2.05 (m, 2 H), 2.11 (ddd, J = 9.6, 9.6 and 5.2 Hz, 1 H), 2.68 (ddd, J = 10.0, 10.0 and 5.6 Hz, 1 H), 3.57 (dt, J = 10.0 and 7.6 Hz, 1 H), 3.92 (q, J = 7.2 Hz, 2 H), 4.51 (d, J = 10.0 Hz, 1 H), 4.81 (brs, 2 H), 7.25–7.29 (m, 2 H), 7.29–7.35 (m, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.1, 20.1, 21.6, 24.0 (2C), 34.2, 42.5, 49.1, 50.1, 60.3, 78.5, 81.2, 113.0, 127.1, 128.0, 128.3, 140.8, 145.9, 173.5; IR (KBr, neat): 2954, 2928, 2869, 1730, 1644, 1371, 1173, 1093, 1066, 849, 699 cm^{-1}. HRMS (APCI) cald for $C_{21}H_{30}O_3$ $(M + H)^+$ requires 331.2273; found 331.2262. APCI-MS: *m/z* (relative intensity): 331.2 ($(M + H)^+$, 25%), 329.2 (11), 285.2 (7), 245.2 (16), 178.1 (6), 177.1 (37), 125.1 (9), 124.1 (100).

(2*S,3*R**,5*S**,6*R**)-Ethyl tetrahydro-2-phenyl-5-(prop-1-en-2-yl)-6-*p*-tolyl-2*H*-pyran-3-carboxylate (12a)**

Colourless oil (262 mg, 72%); ^1H NMR (400 MHz, $CDCl_3$): δ 0.89 (t, J = 7.2 Hz, 3 H), 1.47 (s, 3 H), 2.12 (ddd, J = 14.0, 12.8 and 5.2 Hz, 1 H), 2.23 (ddd, J = 14.0, 4.4 and 4.0 Hz, 1 H), 2.32 (s, 3 H), 3.01–3.03 (m, 1 H), 3.15 (ddd, J = 12.8, 10.4 and 4.0 Hz, 1 H), 3.83 (q, J = 7.2 Hz, 2 H), 4.38 (d, J = 10.4 Hz, 1 H), 4.70 (brs, 1 H), 4.72 (brs, 1 H), 4.86 (d, J = 3.2 Hz, 1 H), 7.12 (d, J = 8.0 Hz, 2 H), 7.18–7.21 (m, 1 H), 7.24–7.29 (m, 2 H), 7.32–7.37 (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.0, 21.4, 21.9, 32.8, 45.1, 45.7, 60.0, 79.4, 84.9, 112.7, 125.7, 127.3, 127.6, 128.0, 128.9, 137.4, 138.4, 140.7, 145.9, 172.4; IR (KBr, neat): 2926, 2854, 1731, 1644, 1451, 1373, 1174, 1067, 1028, 814, 748 cm^{-1}. HRMS (APCI) cald for $C_{24}H_{28}O_3$ $(M + H)^+$ requires 365.2116; found 365.2108. APCI-MS: *m/z* (relative intensity): 365.2 ($(M + H)^+$, 7%), 301.1 (1), 274.1 (4), 125.1 (9), 124.1 (97), 123.0 (100).

(2*S,3*R**,5*S**,6*R**)-Ethyl 6-(4-bromophenyl)-tetrahydro-2-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (12b)**

Colourless oil (249 mg, 58%); ^1H NMR (400 MHz, $CDCl_3$): δ 0.88 (t, J = 7.2 Hz, 3 H), 1.48 (s, 3 H), 2.11 (ddd, J = 13.6, 12.8 and 4.8 Hz, 1 H), 2.23 (ddd, J = 13.6, 4.0 and 2.0 Hz, 1 H), 2.98–3.02 (m, 1 H), 3.10 (ddd, J = 12.8, 10.0 and 4.0 Hz, 1 H), 3.84 (q, J = 7.2 Hz, 2 H), 4.38 (d, J = 10.0 Hz, 1 H), 4.69 (brs, 1 H), 4.75 (brs, 1 H), 4.86 (d, J = 3.2 Hz, 1 H), 7.09 (d, J = 8.0 Hz, 2 H), 7.20–7.36 (m, 5 H), 7.45 (d, J = 8.4 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.0, 21.9, 32.6, 45.2, 45.5, 60.0, 79.3, 84.2, 113.2, 126.1, 127.4, 128.1, 129.4, 130.7, 131.3, 140.3, 140.5, 145.2, 172.3; IR (KBr, neat): 2978, 2934, 2859, 1730, 1644, 1484, 1374, 1174, 1070, 1031, 817, 748 cm^{-1}. HRMS (APCI) cald for $C_{23}H_{25}BrO_3$ $(M + H)^+$ requires 429.1065; found 429.1060 (^{79}Br). APCI-MS: *m/z* (relative intensity): 431.1 ($(M + H)^+$, 1%, ^{81}Br), 429.1 ($(M + H)^+$, 1, ^{79}Br), 264.2 (7), 263.2 (39), 245.1 (56), 178.1 (13), 177.1 (100), 131.0 (18), 124.1 (90), 82.0 (11).

(2*S,3*R**,5*S**,6*R**)-Ethyl 6-(4-chlorophenyl)-tetrahydro-2-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (12c)**

Colourless oil (212 mg, 55%); ^1H NMR (400 MHz, $CDCl_3$): δ 0.88 (t, J = 7.2 Hz, 3 H), 1.48 (s, 3 H), 2.12 (ddd, J = 14.0, 12.8 and 4.8 Hz, 1 H), 2.23 (ddd, J = 14.0, 4.0 and 2.0 Hz, 1 H), 2.99–3.03 (m, 1 H), 3.10 (ddd, J = 12.8, 10.4 and 4.0 Hz, 1 H), 3.84 (q, J = 7.2 Hz, 2 H), 4.40 (d, J = 10.4 Hz, 1 H), 4.69 (brs, 1 H), 4.75 (brs, 1 H), 4.86 (d, J = 3.2 Hz, 1 H), 7.20–7.31 (m, 5 H), 7.35(d, J = 8.8 Hz, 2 H), 7.39 (J = 8.4 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 13.9, 21.9, 32.5, 45.2, 45.5, 60.0, 79.3, 84.2, 113.1, 125.6, 127.4, 128.1, 128.3, 129.0, 130.3, 140.0, 140.3, 145.2, 172.2; IR (KBr, neat): 2978, 2933, 2857, 1730,

1644, 1452, 1374, 1174, 1088, 1069, 895, 748 cm^{-1}. HRMS (APCI) cald for $C_{23}H_{25}ClO_3$ $(M + H)^+$ requires 385.1570; found 385.1565 (^{35}Cl). APCI-MS: *m/z* (relative intensity): 387.1 ($(M + H)^+$, 1%, ^{37}Cl), 385.1 ($(M + H)^+$, 3, ^{35}Cl), 289.2 (6), 263.2 (12), 245.1 (17), 197.1 (10), 177.1 (33), 157.1 (4), 125.1 (10), 124.1 (100), 123.1 (16), 99.0 (8), 82.0 (29).

(2*S,3*R**,5*S**,6*R**)-Ethyl 6-(4-(methoxycarbonyl)phenyl)-tetrahydro-2-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (12d)**

Colourless oil (253 mg, 62%); ^1H NMR (400 MHz, $CDCl_3$): δ 0.90 (t, J = 7.2 Hz, 3 H), 1.46 (s, 3 H), 2.13 (ddd, J = 14.0, 12.8 and 4.8 Hz, 1 H), 2.25 (ddd, J = 14.0, 4.0 and 2.4 Hz, 1 H), 3.02–3.06 (m, 1 H), 3.12 (ddd, J = 12.8, 10.4 and 4.0 Hz, 1 H), 3.86 (q, J = 7.2 Hz, 2 H), 3.91 (s, 3 H), 4.48 (d, J = 10.4 Hz, 1 H), 4.69 (brs, 1 H), 4.74 (brs, 1 H), 4.88 (d, J = 3.2 Hz, 1 H), 7.20–7.24 (m, 1 H), 7.26–7.32 (m, 2 H), 7.34–7.38 (m, 2 H), 7.53 (d, J = 8.4 Hz, 2 H), 8.01 (d, J = 8.4 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 13.9, 21.9, 32.5, 45.3, 45.5, 52.1, 59.9, 79.3, 84.5, 113.3, 125.6, 127.4, 127.6, 128.1, 128.4, 129.5, 140.2, 145.0, 146.5, 167.2, 172.2; IR (KBr, neat): 2983, 2951, 2857, 1725, 1644, 1372, 1276, 1177, 1100, 1070, 898, 758 cm^{-1}. HRMS (APCI) cald for $C_{25}H_{28}O_5$ $(M + H)^+$ requires 409.2015; found 409.2021. APCI-MS: *m/z* (relative intensity): 409.0 ($(M + H)^+$, 67%), 391.0 (20), 359.0 (9), 317.0 (11), 245.0 (9), 215.0 (9), 173.0 (5), 150.0 (13), 137.0 (26), 124.0 (100).

(2*S,3*R**,5*S**,6*S**)-Ethyl tetrahydro-2-phenyl-5-(prop-1-en-2-yl)-6-propyl-2*H*-pyran-3-carboxylate (12e)**

Colourless oil (285 mg, 90%); ^1H NMR (400 MHz, $CDCl_3$): δ 0.83 (t, J = 7.2 Hz, 3 H), 0.91 (t, J = 6.8 Hz, 3 H), 1.39–1.46 (m, 1 H), 1.49–1.68 (m, 3 H), 1.72 (s, 3 H), 1.94 (ddd, J = 13.6, 13.2 and 5.6 Hz, 1 H), 2.10 (ddd, J = 13.6, 3.6 and 2.0 Hz, 1 H), 2.79 (ddd, J = 13.2, 10.4 and 3.6 Hz, 1 H), 2.94–2.98 (m, 1 H), 3.47 (ddd, J = 10.4, 7.2 and 7.2 Hz, 1 H), 3.77 (q, J = 7.2 Hz, 2 H), 4.69 (d, J = 3.2 Hz, 1 H), 4.83 (brs, 1 H), 4.84 (brs, 1 H), 7.20–7.26 (m, 2 H), 7.28–7.36 (m, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 13.8, 14.3, 18.7, 20.3, 32.6, 35.6, 43.9, 45.3, 59.7, 78.9, 80.8, 112.6, 125.5, 127.0, 128.0, 141.2, 146,5, 172.3; IR (KBr, neat): 2958, 2934, 2871, 1732, 1643, 1378, 1175, 1098, 1047, 894, 746 cm^{-1}. HRMS (APCI) cald for $C_{20}H_{28}O_3$ $(M + H)^+$ requires 317.2116; found 317.2110. APCI-MS: *m/z* (relative intensity): 317.0 ($(M + H)^+$, 47%), 299.0 (11), 245.0 (21), 219.0 (36), 199.0 (15), 173.0 (12), 124.0 (100), 123.0 (28), 101.0 (12), 82.0 (45).

(2*S,3*R**,5*S**,6*S**)-Ethyl 6-cyclohexyl-tetrahydro-2-phenyl-5-(prop-1-en-2-yl)-2*H*-pyran-3-carboxylate (12f)**

Colourless oil (285 mg, 80%); ^1H NMR (400 MHz, $CDCl_3$): δ 0.84 (t, J = 7.2 Hz, 3 H), 1.15–1.28 (m, 4 H), 1.43–1.66 (5 H), 1.72 (s, 3 H), 1.75–1.87 (m, 2 H), 1.94 (ddd, J = 13.6, 12.4 and 5.2 Hz, 1 H), 2.08 (ddd, J = 13.6, 4.4 and 2.0 Hz, 1 H), 2.90–2.93 (m, 1 H), 3.04 (ddd, J = 12.4, 10.0 and 4.0 Hz, 1 H), 3.32 (d, J = 10.0 Hz, 1 H), 3.77 (q, J = 7.2 Hz, 2 H), 4.64 (d, J = 3.2 Hz, 1 H), 4.83 (brs, 1 H), 4.84 (brs, 1 H), 7.20–7.40 (m, 5 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.0, 20.2, 25.7, 26.8, 26.9, 27.0, 31.3, 32.8, 39.7, 40.1, 45.6, 59.8, 78.9, 84.8, 112.8, 125.6, 127.0, 128.0, 141.5, 146.6, 172.3; IR (KBr, neat): 2933, 2854, 1737, 1643, 1373, 1168, 1157, 1099, 1058, 890, 751 cm^{-1}. HRMS (APCI) cald for $C_{23}H_{32}O_3$ $(M + H)^+$ requires 357.2429; found 357.2435. APCI-MS: *m/z* (relative intensity): 357.3 ($(M + H)^+$, 7%), 219.1 (3), 178.1 (4), 125.1 (11), 124.1 (100), 123.1 (14), 82.0 (25).

(2*S,3*S**,4a*R**,10b*R**)-Ethyl 2,3,4,4a,5,10b-hexahydro-5,5-dimethyl-2-phenylpyrano[3,2-*c*]chromene-3-carboxylate (13)**

Colourless solid; M.P.: 166–169 °C (213 mg, 58%); ^1H NMR (400 MHz, $CDCl_3$): δ 1.00 (t, J = 7.2 Hz, 3 H), 1.27 (s, 3 H), 1.45 (s, 3 H), 1.82 (ddd, J = 12.4, 12.0 and 12.0 Hz, 1 H), 1.91 (ddd, J = 12.4, 4.0 and 3.2 Hz, 1 H), 2.21 (ddd, J = 12.0, 10.0 and 3.2 Hz, 1 H), 2.77 (ddd, J = 12.0, 10.0 and 4.0 Hz, 1 H), 3.94 (q, J = 7.2 Hz, 2 H), 4.53 (d, J = 10.0 Hz, 1 H), 4.77 (d, J = 10.0 Hz, 1 H), 6.79 (d, J = 8.4 Hz, 1 H), 6.84–6.88 (m, 1 H), 7.14–7.19 (m, 1 H), 7.28–7.43 (m, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.1, 20.7, 27.9, 29.6, 43.9, 50.4, 60.7, 73.8, 78.3, 81.5, 116.9, 120.1, 122.0, 126.6, 127.4, 128.4 (2C), 129.2, 140.1, 152.8, 173.2; IR (KBr, neat): 2978, 2934, 2855, 1731, 1612, 1458, 1371, 1167, 1122, 1065, 759, 704; cm^{-1}. HRMS (APCI) cald for $C_{23}H_{26}O_4$ $(M + H)^+$ requires 367.1909; found 367.1905. APCI-MS: *m/z* (relative intensity): 367.2 ($(M + H)^+$, 1%), 366.1 (2), 351.1 (3), 261.1 (2), 177.1 (3), 125.1 (6), 124.1 (80), 123.0 (100).

(2*S,3*R**,4a*R**,10b*R**)-Ethyl 2,3,4,4a,5,10b-hexahydro-5,5-dimethyl-2-phenylpyrano[3,2-*c*]chromene-3-carboxylate (14)**

Colourless solid; M.P.: 150–152 °C (202 mg, 55%); ^1H NMR (400 MHz, $CDCl_3$): δ 0.77 (t, J = 7.2 Hz, 3 H), 1.23 (s, 3 H), 1.44 (s, 3 H), 1.74 (ddd, J = 13.2, 12.8 and 5.2 Hz, 1 H), 2.27 (ddd, J = 13.2, 3.8 and 2.0 Hz, 1 H), 2.57 (ddd, J = 12.8, 10.8 and 3.8 Hz, 1 H), 3.06–3.11 (m, 1 H), 3.67–3.79 (m, 2 H), 4.45 (d, J = 10.8 Hz, 1 H), 4.96 (d, J = 3.2 Hz, 1 H), 6.80 (d, J = 8.0 Hz, 1 H), 6.88–6.92 (m, 1 H), 7.15–7.19 (m, 1 H), 7.23–7.42 (m, 5 H), 7.52 (d, J = 7.6 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 13.8, 20.4, 27.8, 28.1, 39.6, 45.2, 60.0, 74.5, 78.4, 79.2, 116.8, 120.0, 122.3, 125.7, 126.5, 127.3, 128.1, 129.0, 140.6, 153.0, 171.8; IR (KBr, neat): 2979, 2942, 2862, 1731, 1607, 1459, 1371, 1172, 1100, 1076, 760, 748 cm^{-1}. HRMS (APCI) cald for $C_{23}H_{26}O_4$ $(M + H)^+$ requires 367.1909; found 367.1914. APCI-MS: *m/z* (relative intensity): 367.2 ($(M + H)^+$, 1%), 366.2 (1), 311.2 (10), 261.2 (3), 178.1 (3), 177.1 (17), 125.1 (10), 124.1 (100).

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12 The crystallographic data for compounds **4g**, **11f**, **13** and **14** have been deposited with the Cambridge Crystallographic Data Centre as Supplementary publication numbers CCDC 819363, 819365, 819364 and 819366†.