Regioselective Synthesis of Trichloromethyl-Substituted Salicylates and Cyclohexenones by One-Pot Cyclizations of 1,3-Bis(trimethylsilyloxy)buta-1,3-dienes

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A variety of 6-(trichloromethyl)salicylates (=2-hydroxy-6-(trichloromethyl)benzoates) were prepared by $TiCl_4$-mediated cyclization of 1,3-bis(trimethylsilyloxy)buta-1,3-dienes with 1,1,1-trichloro-4,4-dimethoxybut-3-en-2-one. The employment of trimethylsilyl trifluoromethanesulfonate (Me_3SiOTf) as *Lewis* acid resulted in the formation of trichloromethyl-substituted cyclohexenones. The cyclizations proceeded with good-to-very-good regioselectivities.

Introduction. – The trichloromethyl (Cl_3C) group plays an important role in medicinal and agricultural chemistry. A prominent example is the insecticide DDT ('dichlorodiphenyltrichloroethane' (=1,1,1-trichloro-2,2-bis(4-chlorphenyl)ethane); **I**; *Fig. 1*). 1,2,3,4-tetrahydro-1-(trichloromethyl)-β-carboline (TaClo; **II**; *Fig. 1*), a putative *in vivo* condensation product of chloralhydrate and tryptamine, constitutes a mammalian alkaloid and a potent neurotoxin which is capable of inducing a slowly developing degeneration of the dopaminergic system in rats [1]. Its effect on the oxidative phosphorylation system has been studied with respect to the understanding of *Parkinson*'s disease [2]. 2-Amino-4,6-bis(trichloromethyl)-1,3,5-triazines and *N*-[4-amino-6-(trichloromethyl)-1,3,5-triazin-2-yl]-*N*′-(4-chlorophenyl)guanidines, **III**, have been reported to show antimalarial activity [3]. Anxiolytic effects in mice have been reported for 4-phenyl-2-trichloromethyl-3*H*-1,5-benzodiazepine hydrogen sulfate [4].

Cl_3C-Substituted arenes are available by exhaustive chlorination of the corresponding Me-substituted derivatives. However, this established approach can suffer from various side reactions, such as chlorination of C=C bonds and of the arene system. Therefore, we considered to develop a building-block approach which relies on the employment of suitable Cl_3C-substituted enones in cyclization reactions. 1,3-Bis(trimethylsilyloxy)buta-1,3-dienes, first developed by *Chan* and co-workers, represent versatile synthetic building blocks and can be regarded as masked 1,3-dicarbonyl

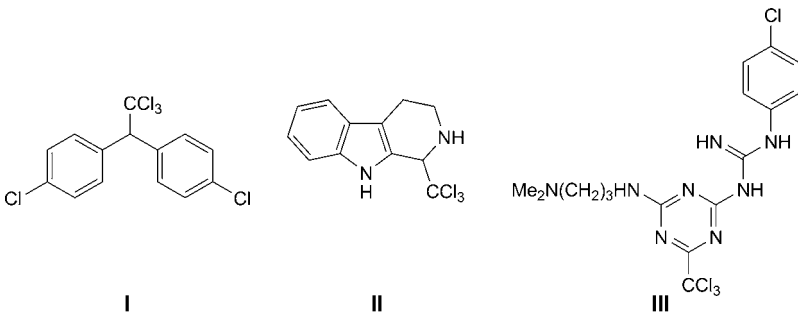
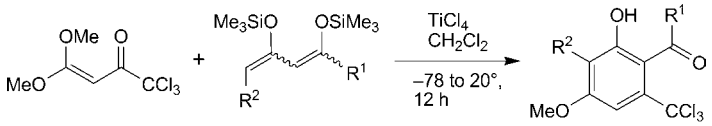


Fig. 1. *Cl_3C-Substituted compounds used in agricultural and medicinal chemistry*

dianions [5][1]). In recent years, we reported the synthesis of various chlorinated salicylic acid derivatives by formal [3 + 3] cyclization reactions of 1,3-bis(trimethylsilyloxy)buta-1,3-dienes [7]. We also reported the synthesis of salicylates containing CF_3, CF_2Cl, CF_2Br, and $CHCl_2$ substituents by reaction of 1,3-bis(trimethylsilyloxy)buta-1,3-dienes with substituted enones [8]. The Cl_2CH substituent was subsequently transformed into the corresponding aldehyde group to furnish highly functionalized benzene derivatives. Herein, we report, for the first time, the synthesis of various Cl_3C-substituted salicylates and cyclohexenones, which are not readily available by other methods.

Results and Discussion. – 1,1,1-Trichloro-4,4-dimethoxybut-3-en-2-one (**1**), a colorless solid, was prepared in 51% yield according to a known procedure [9] by reaction of trichloroacetic anhydride (65% yield; available from 2,2,2-trichloroacetic acid) with trimethyl orthoacetate. The $TiCl_4$-mediated cyclization of **1** with 1,3-bis(silyloxy)buta-1,3-dienes **2a**–**2j**, available from the corresponding β-keto esters in two steps [5], afforded novel 6-(trichloromethyl)salicylates (= 2-hydroxy-6-(trichloromethyl)benzoates) **3a**–**3j** in 20–60% yields (*Scheme 1* and *Table 1*). During the optimization, it proved to be important to carry out reactions in a highly concentrated solution, and to use an excess of dienes **2** (*Table 2*).

Scheme 1. *Synthesis of* **3a**–**3j**



The structures of **3a** and **3d** were independently confirmed by X-ray crystal-structure analysis (*Figs. 2* and *3*). The torsion angle O1–C7–C1–C2 is 37.3(2)° for **3a** and 34.3(2)° for **3d**. Therefore, they allow the formation of intramolecular H-bonds

[1]) For a review of 1,3-bis(trimethylsilyloxy) 1,3-dienes in general, see [6a]; for a review of [3 + 3] cyclizations, see [6b].

Table 1. *Synthesis of* **3a**–**3j**

Compound **2**	R^1	R^2	rs[a])	Compound **3**	Yield [%][b])
2a	MeO	H	> 98 : 2	**3a**	30
2b	BnO	H	> 98 : 2	**3b**	30
2c	MeO	Me	10 : 1	**3c**	42
2d	MeO	Et	> 98 : 2	**3d**	46
2e	MeO	Allyl	> 98 : 2	**3e**	32
2f	MeO	^{i}Pent[c])	10 : 3	**3f**	41
2g	MeO	$Cl(CH_2)_3$	> 98 : 2	**3g**	45
2h	MeO	$Cl(CH_2)_4$	5 : 1	**3h**	35
2i	MeO	$Ph(CH_2)_2$	5 : 1	**3i**	60
2j	MeO	$(4\text{-F–}C_6H_4)CH_2$	> 98 : 2	**3j**	20

[a]) Regioselectivity (based on ^{1}H-NMR spectra of the isolated products); in the minor component, the positions of MeO and CCl_3 are exchanged. [b]) Yields of the isolated products. [c]) ^{i}Pert = Isopentyl (= 3-methylbutyl).

Table 2. *Optimization of the Yield of* **3a**

Ratio **1**/**2** [mmol]	*V* (CH_2Cl_2) [ml]	Yield of **3a**[a]) [%]
1 : 2	1	28
1 : 1	2	10
1 : 2	2	30
1 : 3	2	25
1 : 2	5	27

[a]) Yields of the isolated product.

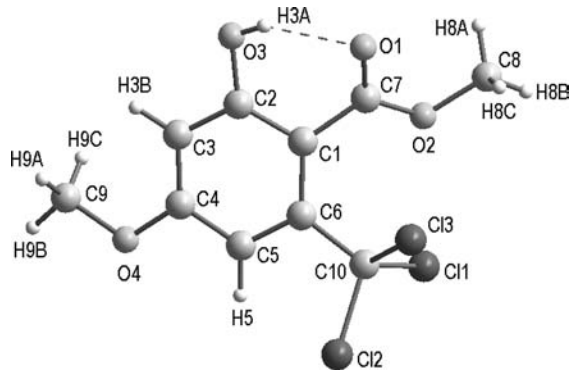


Fig. 2. *Molecular structure of* **3a**[2])

O3–H3 ··· O1 (**3a**: O3–H3 0.81(2), H3 ··· O1 1.89(2), O3 ··· O1 2.628(2) Å, O3–H3 ··· O1 152(2)°; **3d**: O3–H3A 0.77(2), H3A ··· O1 1.94(2), O3 ··· O1 2.604(2) Å, O3–H3A ··· O1 144(2)°). These intramolecular H-bonds are also present in solution, which can

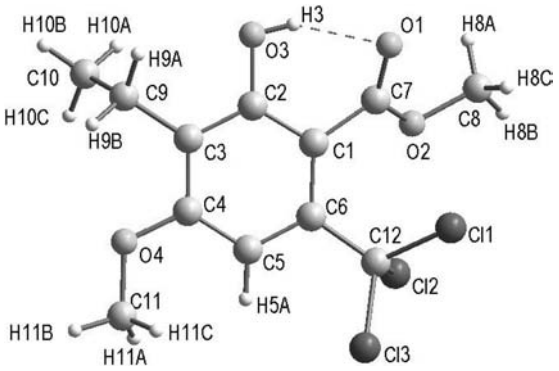


Fig. 3. *Molecular structure of* **3d**[2])

be evidenced by low-field ^{1}H-NMR chemical shifts (12 ppm) of the corresponding H-atoms[2]).

The formation of **3a** can be explained, based on experimental studies carried out on a related substrate [10], by formation of allylic cation **A**, attack of **2a** to give intermediates **B** and **C**, cyclization (intermediate **D**), and aromatization (*Scheme 2*).

All attempts to hydrolize the Cl_3C group to a carboxylic acid function failed (formation of complex mixtures). However, this transformation is not of preparative importance, as we have earlier reported that the corresponding products are available by cyclization of 1,3-bis(silyloxy)buta-1,3-dienes with ester substituted 3-alkoxy 2-en-1-ones [11]. Therefore, we did not further investigate transformations of the Cl_3C group. In fact, the protocol reported in this work is important for the synthesis of Cl_3C-substituted arenes, which are important in their own right (as discussed in *Introduction*).

The cyclization of 1,1,1-trichloro-4,4-dimethoxybut-3-en-2-one (**1**) with 1,3-bis(silyloxy)buta-1,3-dienes **2** (2 equiv.), carried out using trimethylsilyl trifluoromethanesulfonate (Me_3SiOTf) instead of $TiCl_4$, afforded Cl_3C-substituted cyclohexenones **4a**–**4o** (*Scheme 3* and *Table 3*). Surprisingly, despite the use of HCl (10%) for the aqueous workup, no aromatization took place. This might be explained by the strong electron-withdrawing character of the Cl_3C group which destabilizes a cation located at the neighbouring C-atom.

The reaction conditions were optimized for the synthesis of **4a** (*Table 4*). The results evidence that the best yields were obtained when the reactions were carried out in highly concentrated solutions.

The structures of **4e**, **4f**, and **4n** were independently confirmed by X-ray crystal-structure analysis (*Figs. 4–6*). The crystal structures unambiguously establish the relative configuration of these molecules indicating that the OH and the ester groups are located *cis* to each other.

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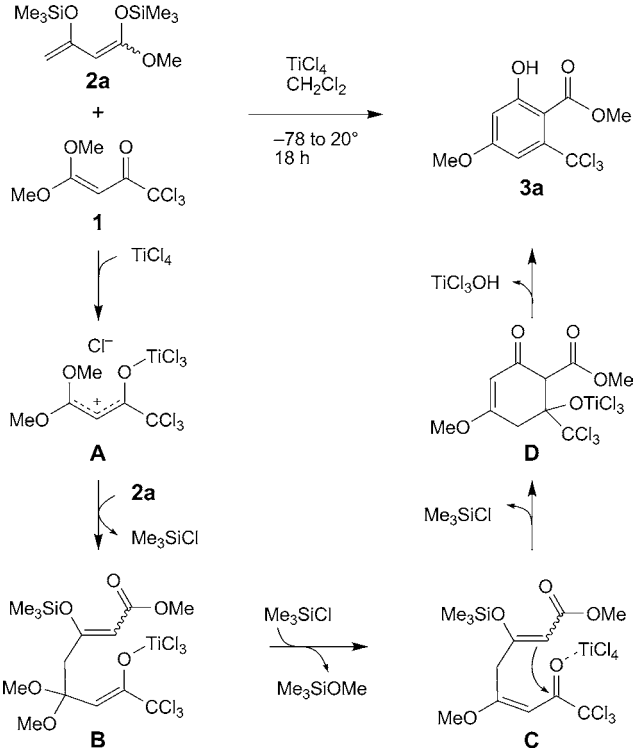
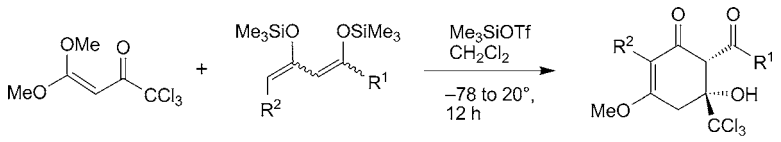
[2]) CCDC 915390–315394 contain all crystallographic details of this publication and is available free of charge at www.ccdc.cam.ac.uk/conts/retrieving.html or can be ordered from the following address: *Cambridge Crystallographic Data Centre*, 12 Union Road, GB-Cambridge CB21EZ; Fax: (+44)1223-336-033; or deposit@ccdc.cam.ac.uk.

Scheme 2. *Proposed Mechanism of the Formation of* **3a**



Scheme 3. *Synthesis of* **4a**–**4o**



1 **2b**, **2d**, **2g**, **2h**, **2k** – **2t** **4a** – **4o**

The formation of products **4** might be explained by the mechanism outlined in *Scheme 4*. Allylic cation **E** is formed from 1,1,1-trichloro-4,4-dimethoxybut-3-en-2-one (**1**). Subsequently, **E** is attacked by the terminal C-atom of the 1,3-bis(trimethylsilyloxy)buta-1,3-diene to give intermediate **F**. The elimination of Me_3SiOMe gives intermediate **G**. Subsequent cyclization with the central C-atom of the diene affords intermediate **H** which, after elimination of silanol, affords product **4a**. Due to the strong electron-withdrawing character of the Cl_3C group, the elimination of H_2O and aromatization during the aqueous workup with acid do not occur. This result also suggests that the aromatization in the case of the formation of products **3** occurs before the aqueous workup and is mediated by $TiCl_4$.

Table 3. *Synthesis of* **4a**–**4o**

2	**4**	R^1	R^2	**4** [%][a])
2k	**4a**	^{i}BuO	H	44
2l	**4b**	^{i}PentO	H	45
2m	**4c**	OctO	H	60
2b	**4d**	BnO	H	57
2d	**4e**	MeO	Et	66
2n	**4f**	EtO	$Me(CH_2)_4$	70
2f	**4g**	MeO	$Me_2CH(CH_2)_2$	33
2o	**4h**	EtO	$Me(CH_2)_5$	53
2p	**4i**	MeO	$Me(CH_2)_7$	57
2q	**4j**	MeO	$Me(CH_2)_8$	66
2r	**4k**	EtO	$Me(CH_2)_9$	40
2s	**4l**	MeO	$Me(CH_2)_{11}$	72
2t	**4m**	MeO	$Me(CH_2)_{15}$	64
2g	**4n**	MeO	$Cl(CH_2)_3$	56
2h	**4o**	MeO	$Cl(CH_2)_4$	76

[a])Yields of the isolated products.

Scheme 4. *Proposed Mechanism of the Formation of* **4a**

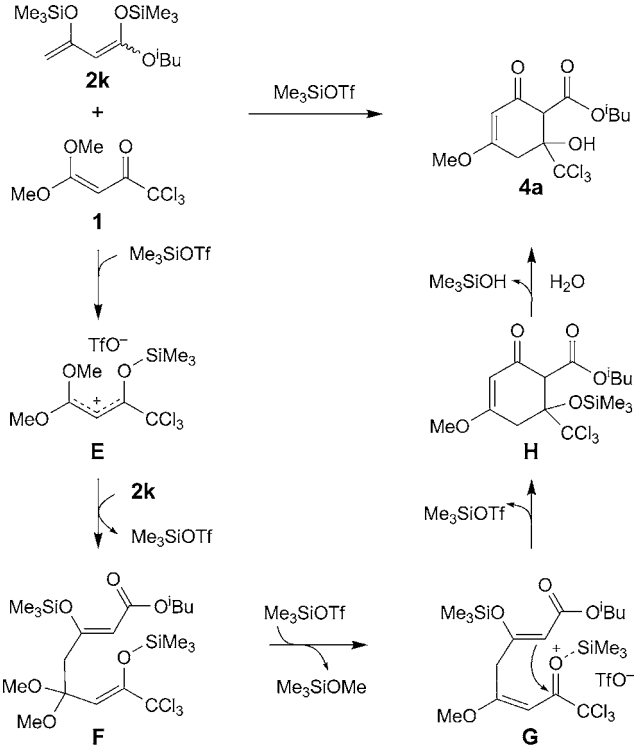


Table 4. *Optimization of the Yield of* **4a**

n (**1**) [mmol]	*n* (**2**) [mmol]	*n* (Me_3SiOTf) [mmol]	*V* (solvent) [ml]	Solvent	Yield of **4a**[a]) [%]
1	2	1	1	CH_2Cl_2	34
1	2	1	2	CH_2Cl_2	45
1	2	1	5	CH_2Cl_2	36
1	1	1	10	CH_2Cl_2	33
1	2	1	2	THF	0
1	2	1	2	Acetone	0

[a])Yield of the isolated products.

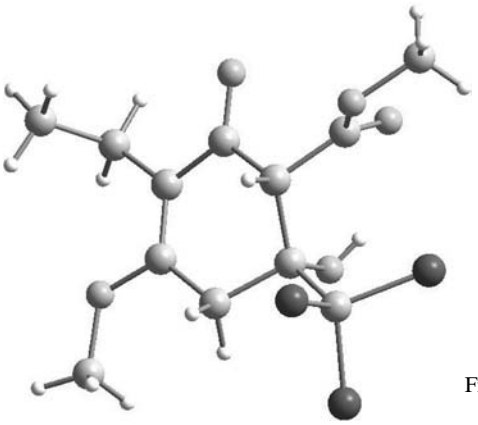


Fig. 4. *Molecular structure of* **4e**[2])

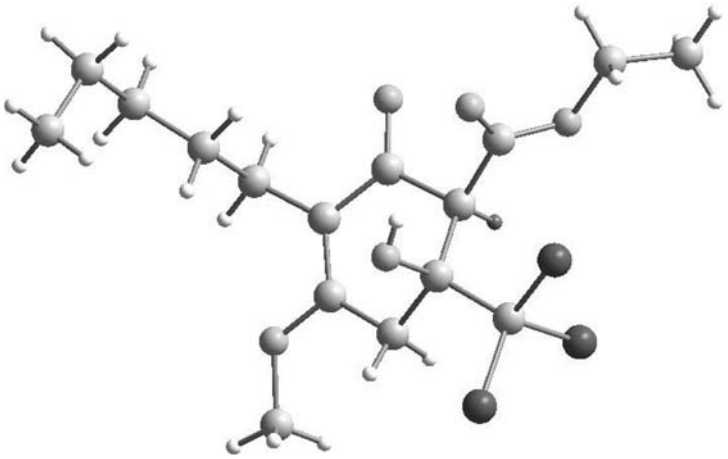


Fig. 5. *Molecular structure of* **4f**[2])

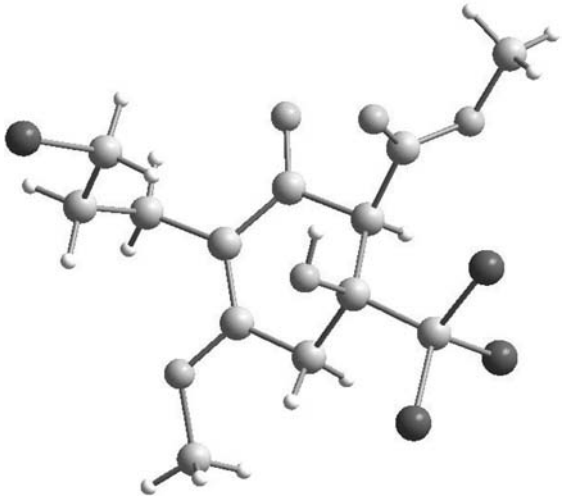


Fig. 6. *Molecular structure of* **4n**[2])

In the ^{1}H-NMR spectrum of **4**, two characteristic *doublet*s were observed for the H-atoms at C(5) in the range of δ(H) 3.04 – 3.27 ($^2J_{AB} \approx 17.6$). The *AB* signal pattern of the CH_2 group is caused by the neighbored stereogenic centers (C(6) and C(1)). *Singlet*s were detected for H–C(1) and HO–C(6) at δ(H) 4.15 – 4.21 and 5.54 – 6.00, respectively. The ^{1}H,^{1}H-NOESY experiments showed correlations between MeO–C(4) and the neighboring H-atom or alkyl group at C(3).

In conclusion, we have reported a convenient approach to Cl_3C-substituted salicylates and cyclohexenones. The type of product formed depends on the type of *Lewis* acid employed.

Experimental Part

General. All glassware used was heated and dried for several times under vacuum. All reactions were carried out under an inert atmosphere. The solvent (CH_2Cl_2, 99.8%, extra anh. over molecular sieves, stabilized) was obtained from *ACROS Organics*. 1,3-Bis(silyloxy)buta-1,3-dienes **2** were prepared according to a literature procedure from the corresponding β-keto esters in two steps and used within a few days [5]. *1,1,1-Trichloro-4,4-dimethoxybut-3-en-2-one* (**1**) was synthesized as described in [9]. TLC: *Merck* precoated aluminum plates (*Si 60* F_{254}). Column chromatography (CC): *Merck* silica gel *60* (SiO_2; 0.043 – 0.06 mm). NMR Spectra: *Bruker ARX 300* and *Bruker ARX 400* spectrometers; with referenced to signals of $CDCl_3$, resp. GC/MS: *Agilent HP-5890* instrument with an *Agilent HP-5973* mass-selective detector (EI) and *HP-5* cap. column using He as carrier gas. ESI-MS: *Agilent 1969A* TOF mass-spectrometer. Elemental analysis: *C/H/N/S – Microanalysator TruSpec CHNS* (*Leco*).

General Procedure for the Synthesis of **3a** – **3j**. To a CH_2Cl_2 soln. (2 ml/1 mmol of **1**) of **1** (1 mmol) were added **2** (2 mmol) and, subsequently, $TiCl_4$ (0.1 ml, 1 mmol) at $-78°$. The soln. was allowed to warm to 20° during 12 – 14 h with stirring. HCl (10%, 15 ml) was added, and the org. and aq. layers were separated. The latter was extracted with CH_2Cl_2 (3×10 ml). The combined org. layers were dried (Na_2SO_4), filtered, and the filtrate was concentrated *in vacuo*. The residue was purified by CC.

Methyl 2-Hydroxy-4-methoxy-6-(trichloromethyl)benzoate (**3a**). From **1** (0.233 g, 1.0 mmol), *1-methoxy-1,3-bis(trimethylsilyloxy)buta-1,3-diene* (**2a**; 0.520 g, 2.0 mmol), and $TiCl_4$ (0.1 ml, 1 mmol) in

CH_2Cl_2 (2 ml). Yield: 0.086 g (30%). Slightly yellow solid. M.p. 93–95°. IR (ATR): 3214*w*, 3120*w*, 3025*w*, 3011*w*, 2973*w*, 2954*w*, 2844*w*, 2616*w*, 1737*w*, 1672*s*, 1612*s*, 1570*m*, 1481*w*, 1442*m*, 1425*s*, 1326*s*, 1250*s*, 1193*s*, 1152*s*, 956*s*, 766*s*. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.85 (*s*, MeO); 3.92 (*s*, MeO); 6.54 (*d*, ^4J = 3.0, CH); 7.34 (*d*, ^4J = 2.4, CH); 9.61 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 52.2, 55.8 (MeO); 96.4 (Cl_3C); 102.3 (Ar); 105.9 (C); 110.0 (CH); 144.3, 161.5, 162.1, 170.0 (C). GC/MS (EI, 70 eV): 300 (31, M^+), 299 (3, M^+), 298 (34, M^+), 270 (34), 268 (100), 267 (31), 266 (97), 233 (30), 231 (38), 227 (41), 212 (58), 210 (27), 205 (29), 203 (40), 149 (33). HR-EI-MS (70 eV): 299.9534 (M^+, $C_{10}H_9Cl_2{}^{37}ClO_4^+$; calc. 299.9531). Anal. calc. for $C_{10}H_9Cl_3O_4$ (299.54): C 40.10, H 3.03; found: C 40.27, H 3.49.

Benzyl 2-Hydroxy-4-methoxy-6-(trichloromethyl)benzoate (**3b**). From **1** (0.233 g, 1.0 mmol), *1-(benzyloxy)-1,3-bis(trimethylsilyloxy)but-1,3-ene* (**2b**; 0.673 g, 2.0 mmol), and $TiCl_4$ (0.1 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.110 g (30%). Dark-yellow solid. M.p. 88–89°. IR (ATR): 3235*w*, 3087*w*, 3063*w*, 3027*w*, 2961*w*, 2936*w*, 2685*w*, 1703*s*, 1606*s*, 1589*m*, 1497*m*, 1452*m*, 1257*s*, 1158*s*, 957*s*, 768*s*, 708*s*, 579*s*. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.83 (*s*, MeO); 6.37 (*s*, CH_2); 6.53 (*d*, ^4J = 2.4, CH); 7.30–7.46 (*m*, CH, 5 arom. H); 9.49 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 55.7 (MeO); 68.2 (CH_2); 96.3 (Cl_3C); 102.3 (Ar); 105.2 (C); 109.9, 128.5, 128.7, 129.4 (CH); 134.1, 144.2, 161.2, 162.0, 169.4 (C). HR-ESI-MS: 396.9764 ($[M+Na]^+$, $C_{16}H_{13}Cl_3NaO_4^+$; calc. 396.9771).

Methyl 2-Hydroxy-4-methoxy-3-methyl-6-(trichloromethyl)benzoate (**3c**). From **1** (0.233 g, 1.0 mmol), *1-methoxy-1,3-bis(trimethylsilyloxy)pent-1,3-ene* (**2c**; 0.549 g, 2.0 mmol), and $TiCl_4$ (0.1 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.130 g (42%). Mixture of regioisomers (10 : 1). Colorless solid (0.130 g, 42%). ^{1}H-NMR (300 MHz, $CDCl_3$): 2.13 (*s*, Me); 3.92 (br. *s*, 2 MeO); 7.31 (*s*, CH); 9.28 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 8.42 (Me); 52.3, 55.7 (MeO); 97.0 (Cl_3C); 103.6 (Ar); 106.9, 116.4, 141.2, 157.4, 159.3, 170.5 (C).

Methyl 3-Ethyl-2-hydroxy-4-methoxy-6-(trichloromethyl)benzoate (**3d**). From **1** (0.233 g, 1.0 mmol), *1-methoxy-1,3-bis(trimethylsilyloxy)hexa-1,3-diene* (**2d**; 0.576 g, 2.0 mmol), and $TiCl_4$ (0.1 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.152 g (46%). Colorless solid. M.p. 120–122°. IR (ATR): 3254*w*, 3130*w*, 3007*w*, 2968*w*, 2953*w*, 2923*w*, 2874*w*, 2851*w*, 1664*s*, 1602*m*, 1569*m*, 1496*m*, 1435*m*, 1285*s*, 1127*s*, 822*s*, 761*s*, 693*s*, 613*s*. ^{1}H-NMR (300 MHz, $CDCl_3$): 1.10 (*t*, ^3J = 7.5, Me); 2.68 (*q*, ^3J = 7.5, CH_2); 3.91 (*s*, MeO); 3.92 (*s*, MeO); 7.31 (*s*, CH); 9.23 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 12.8 (Me); 16.5 (CH_2); 52.3, 55.7 (MeO); 97.0 (Cl_3C); 103.9 (Ar); 107.1, 122.3, 141.3, 157.2, 159.0, 170.5 (C). GC/MS (EI, 70 eV): 328 (16, M^+), 327 (2, M^+), 326 (17, M^+), 260 (68), 258 (100). HR-EI-MS (70 eV): 325.9867 (M^+, $C_{12}H_{13}Cl_3O_4^+$; calc. 325.9873), 327.9839 (M^+, $C_{12}H_{13}Cl_2{}^{37}ClO_4^+$; calc. 327.9844), 329.9811 (M^+, $C_{12}H_{13}Cl^{37}Cl_2O_4^+$; calc. 329.9814). Anal. calc. for $C_{12}H_{13}Cl_3O_4$ (327.59): C 44.00, H 4.00; found: C 44.04, H 4.34.

Methyl 2-Hydroxy-4-methoxy-3-(prop-2-en-1-yl)-6-(trichloromethyl)benzoate (**3e**). From **1** (0.233 g, 1.0 mmol), *1-methoxy-1,3-bis(trimethylsilyloxy)hepta-1,3,6-triene* **2e** (0.601 g, 2.0 mmol), and $TiCl_4$ (0.1 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.109 g (32%). Colorless oil. IR (ATR): 3409*w*, 3079*w*, 3005*w*, 2950*w*, 2847*w*, 1673*m*, 1638*w*, 1600*m*, 1573*w*, 1497*w*, 1276*s*, 1186*s*, 1155*s*, 1113*s*, 1034*s*, 758*s*, 603*s*, 370*s*. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.42–3.45 (*m*, CH_2); 4.97 (*s*, MeO); 4.97–5.09 (*m*, CH_2); 5.83–5.89 (*m*, 2 CH); 7.33 (*s*, CH); 9.22 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 27.3 (CH_2); 52.3, 55.8 (MeO); 96.9 (Cl_3C); 103.9 (Ar); 107.3 (C); 115.3 (CH_2); 118.0 (C); 134.9, 141.9, 157.3, 159.1, 170.3 (C). GC/MS (EI, 70 eV): 340 (26, M^+), 339 (4, M^+), 338 (28, M^+), 303 (30), 273 (50), 272 (76), 271 (78), 270 (100), 237 (26), 207 (49). HR-EI-MS (70 eV): 337.9871 (M^+, $C_{13}H_{13}Cl_3O_4^+$; calc. 337.9873). Anal. calc. for $C_{13}H_{13}Cl_3O_4$ (339.60): C 45.98, H 3.86; found: C 48.22, H 4.34.

Methyl 2-Hydroxy-4-methoxy-3-(3-methylbutyl)-6-(trichloromethyl)benzoate (**3f**). From **1** (0.233 g, 1.0 mmol), *1-methoxy-7-methyl-1,3-bis(trimethylsilyloxy)octa-1,3-diene* (**2f**; 0.689 g, 2.0 mmol), and $TiCl_4$ (0.1 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.153 g (41%). Mixture of regioisomers (10 : 3). Colorless oil. ^{1}H-NMR (300 MHz, $CDCl_3$): 0.94 (*d*, ^3J = 6.0, 2 Me); 1.32–1.43 (*m*, CH_2); 1.52–1.63 (*m*, CH_2); 2.62–2.68 (*m*, CH_2); 3.91 (*s*, MeO); 3.92 (*s*, MeO); 7.30 (*s*, CH); 9.21 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 21.2 (CH_2); 22.5 (Me); 28.3 (CH); 37.5 (CH_2); 52.3, 55.7 (MeO); 97.1 (Cl_3C); 103.9 (Ar); 107.0, 121.4, 141.2, 157.3, 159.2, 170.5 (C).

Methyl 3-(3-Chloropropyl)-2-hydroxy-4-methoxy-6-(trichloromethyl)benzoate (**3g**). From **1** (0.233 g, 1.0 mmol), *7-chloro-1-methoxy-1,3-bis(trimethylsilyloxy)hepta-1,3-diene* (**2g**; 0.674 g, 2.0 mmol), and $TiCl_4$ (0.1 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.171 g (45%). Slightly yellow solid. M.p. 69–70°. IR (ATR): 3307*w*, 3002*w*, 2950*w*, 2848*w*, 1674*m*, 1600*m*, 1573*w*, 1497*w*, 1435*m*, 1280*s*, 1153*s*,

1109*s*, 761*s*, 697*s*. ^{1}H-NMR (300 MHz, $CDCl_3$): 1.95–2.05 (*m*, CH_2); 2.80 (*t*, ^3J = 7.3, CH_2); 3.54 (*t*, ^3J = 7.4, CH_2); 3.92 (*s*, MeO); 3.93 (*s*, MeO); 7.32 (*s*, CH); 9.32 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 20.7, 31.4, 44.9 (CH_2); 52.4, 55.8 (MeO); 96.9 (Cl_3C); 103.8 (Ar); 107.1 (C); 119.0, 141.9, 157.5, 159.3, 170.4 (C). EI-MS (70 eV): 376 (10, M^+), 309 (93), 307 (100), 246 (34), 244 (53). HR-EI-MS (70 eV): 373.9646 (M^+, $C_{13}H_{14}Cl_4O_4^+$; calc. 373.9640), 375.9615 (M^+, $C_{13}H_{14}Cl_3{}^{37}ClO_4^+$; calc. 375.9611), 377.9588 (M^+, $C_{13}H_{14}Cl_2{}^{37}Cl_2O_4^+$; calc. 377.9581). Anal. calc. for $C_{13}H_{14}Cl_4O_4$ (376.06): C 41.52, H 3.75; found: C 42.32, H 4.14.

General Procedure for the Synthesis of **4a**–**4o**. To a CH_2Cl_2 soln. (2 ml/1 mmol of **1**) of **1** were added **2** (2 mmol) and, subsequently, TMSOTf (0.18 ml, 1 mmol) at −78°. The soln. was allowed to warm to 20° during 12–14 h with stirring. To the soln. was added HCl (10%, 20 ml), and the org. and the aq. layers were separated. The latter was extracted with CH_2Cl_2 (3 × 15 ml). The combined org. layers were dried (Na_2SO_4), filtered, and the filtrate was concentrated *in vacuo*. The residue was purified by CC.

*2-Methylpropyl (1*RS,*6*RS*)-6-Hydroxy-4-methoxy-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4a**). From **1** (0.233 g, 1.0 mmol), *1-(2-methylpropoxy)-1,3-bis(trimethylsilyloxy)buta-1,3-diene* (**2k**; 0.605 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.158 g (44%). Slightly yellow oil. IR (ATR): 3407*w*, 3090*w*, 2958*w*, 2873*w*, 1710*s*, 656*s*, 1617*s*, 1378*s*, 1329*s*, 1229*m*, 1154*s*, 1122*s*, 1032*m*, 991*m*, 900*m*, 846*m*, 805*s*, 791*s*, 616*s*, 529*s*, 469*m*, 396*w*. ^{1}H-NMR (300 MHz, $CDCl_3$): 0.98 (*d*, ^3J = 6.6, Me); 0.98 (*d*, ^3J = 6.6, Me); 1.97–2.09 (*m*, CH); 3.04 (*d*, ^2J = 17.7, H_a–C(5)); 3.18 (*d*, ^2J = 17.4, H_b–C(5)); 3.79 (*s*, MeO); 4.07–4.13 (*m*, CH_2); 4.17 (*s*, H–C(1)); 5.54 (*s*, OH); 5.95 (*s*, H–C(3)). ^{13}C-NMR (75 MHz, $CDCl_3$): 19.0 (Me); 19.1 (Me); 27.4 (CH); 36.6 (CH_2); 55.0 (MeO); 56.5 (CH(1)); 72.7 (C(6)); 84.3 (CH_2(5)); 100.0 (CH(3)); 105.9 (Cl_3C); 171.7 (C=O); 174.6 (C(4)); 190.1 (C=O). HR-ESI-MS: 359.0212 ([M + H]$^+$ (^{35}Cl), $C_{13}H_{18}Cl_3O_5^+$; calc. 359.0214). Anal. calc. for $C_{13}H_{17}Cl_3O_5$ (359.63): C 43.42, H 4.76; found: C 43.78, H 4.880.

*3-Methylbutyl (1*RS,*6*RS*)-6-Hydroxy-4-methoxy-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4b**). From **1** (0.233 g, 1.0 mmol), *1-(3-methylbutoxy)-1,3-(trimethylsilyloxy)buta-1,3-diene* (**2l**; 0.633 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.155 g (45%). Slightly yellow oil. IR (ATR): 3370*w*, 2957*m*, 2871*w*, 1712*m*, 1661*m*, 1619*s*, 1460*m*, 1442*w*, 1381*m*, 1327*m*, 1264*m*, 1224*m*, 1161*s*, 1120*m*, 1092*m*, 1035*m*, 1007*m*, 979*m*, 947*w*, 900*m*, 821*m*, 794*s*, 744*w*, 686*m*, 614*m*, 594*m*, 578*m*, 520*m*, 393*w*. ^{1}H-NMR (300 MHz, $CDCl_3$): 0.93 (*d*, ^3J = 5.3, Me); 0.95 (*d*, ^3J = 5.3, Me); 1.51–1.66 (*m*, CH_2); 1.68–1.83 (*m*, CH); 3.04 (*d*, ^2J = 17.6, H_a–C(5)); 3.18 (*d*, ^2J = 17.6, H_b–C(5)); 3.79 (*s*, MeO); 4.15 (*s*, H–C(1)); 4.19–4.39 (*m*, CH_2); 5.54 (*s*, OH); 5.99 (*s*, H–C(3)). ^{13}C-NMR (75 MHz, $CDCl_3$): 22.6 (Me); 22.7 (Me); 25.2 (CH); 36.9, 37.1 (CH_2); 55.3 (MeO); 56.8 (C(1)); 65.6 (CH_2); 84.6 (C(6)); 100.2 (C(3)); 106.2 (C); 172.0 (C=O); 174.9 (C(4)); 190.4 (C=O). ESI-MS: 373.0372 ([M + H]$^+$ (^{35}Cl), $C_{14}H_{20}Cl_3O_5^+$; calc. 373.0371). Anal. calc. for $C_{14}H_{19}Cl_3O_5$ (373.66): C 45.00, H 5.13; found: C 44.93, H 5.25.

*Octyl (1*RS,*6*RS*)-6-Hydroxy-4-methoxy-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4c**). From **1** (0.233 g, 1.0 mmol), *1-(octyloxy)-1,3-bis(trimethylsilyloxy)buta-1,3-diene* (**2m**; 0.717 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.250 g (60%). Slightly yellow oil. IR (ATR): 3374*w*, 2926*m*, 2855*m*, 1713*m*, 1662*m*, 1620*s*, 1458*m*, 1442*m*, 1380*m*, 1331*m*, 1263*m*, 1224*m*, 1162*s*, 1120*m*, 1091*m*, 1034*m*, 1007*m*, 984*m*, 949*w*, 900*m*, 821*m*, 795*s*, 745*m*, 686*m*, 614*m*, 594*m*, 578*m*, 520*m*, 420*m*, 393*m*. ^{1}H-NMR (300 MHz, $CDCl_3$): 1.25 (*t*, ^3J = 6.5, Me); 1.24–1.42 (*m*, 5 CH_2); 1.67–1.77 (*m*, CH_2); 3.04 (*d*, ^2J = 17.6, H_a–C(5)); 3,18 (*d*, ^2J = 17.6, H_b–C(5)); 3.79 (*s*, MeO); 4.16 (*s*, H–C(1)); 4.18–4.34 (*m*, CH_2); 5.54 (*s*, OH); 5.99 (*s*, H–C(3)). ^{13}C-NMR (75 MHz, $CDCl_3$): 14.4 (Me); 22.9, 26.1, 28.4, 29.4, 29.5, 32.1, 36.9 (CH_2); 55.3 (MeO); 56.8 (C(1)); 67.2 (CH_2); 84.6 (C(6)); 100.3 (C(3)); 106.2 (C); 172.0 (C=O); 174.9 (C(4)); 190.4 (C=O). HR-ESI-MS: 415.0844 ([M + H]$^+$ (^{35}Cl), $C_{17}H_{26}Cl_3O_5^+$; calc. 415.0840). Anal. calc. for $C_{17}H_{25}Cl_3O_5$ (415.74): C 49.11, H 6.06; found: C 48.94, H 6.09.

*Benzyl (1*RS,*6*RS*)-6-Hydroxy-4-methoxy-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4d**). From **1** (0.233 g, 1.0 mmol), *1-(benzyloxy)-1,3-bis(trimethylsilyloxy)buta-1,3-diene* (**2b**; 0.673 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.208 g (57%). Slightly yellow oil. IR (ATR): 3389*w*, 3066*w*, 3033*w*, 2943*w*, 2851*w*, 1714*m*, 1658*m*, 1616*s*, 1498*w*, 1455*m*, 1441*m*, 1380*m*, 1327*m*, 1263*m*, 1224*m*, 1163*s*, 1118*m*, 1082*m*, 1035*m*, 986*m*, 901*m*, 861*w*, 821*m*, 794*s*, 743*m*, 696*m*, 614*m*, 576*m*, 493*m*. ^{1}H-NMR (300 MHz, $CDCl_3$): 3.04 (*d*, ^2J = 17.6, H_a–C(5)); 3.18 (*d*, ^2J = 17.6, H_b–C(5)); 3.79 (*s*, MeO); 4.21 (*s*, H–C(1)); 5.29 (*s*, CH_2); 5.55 (*s*, OH); 5.88 (*s*, H–C(3)); 7.33–7.44 (*m*, 5 arom. H).

^{13}C-NMR (75 MHz, $CDCl_3$): 36.9 (CH_2); 55.4 (MeO); 56.8 (CH(1)); 68.7 (CH_2); 84.6 (C(6)); 100.2 (C(3)); 106.1 (C); 128.9, 129.0, 129.1 (arom. C); 134.6 (arom. C); 171.7 (C=O); 175.0 (C(4)); 190.2 (C=O). Anal. calc. for $C_{16}H_{15}Cl_3O_5$ (393.65): C 48.82, H 3.84; found: C 48.90, H 3.90.

*Methyl (1*RS*,6*RS*)-3-Ethyl-6-hydroxy-4-methoxy-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4e**). From **1** (0.233 g, 1.0 mmol), *1-methoxy-1,3-bis(trimethylsilyloxy)hexa-1,3-diene* (**2d**; 0.575 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.229 g (66%). Slightly yellow oi. IR (ATR): 3342*w*, 3023*w*, 2977*w*, 2961*w*, 2936*w*, 2854*w*, 1704*s*, 1652*m*, 1616*s*, 1435*s*, 1412*m*, 1375*s*, 1342*s*, 1229*s*, 1166*s*, 1113*s*, 1082*s*, 1063*m*, 990*m*, 934*m*, 916*m*, 836*m*, 803*s*, 734*s*, 652*s*, 598*s*, 527*m*, 439*m*, 394*w*. ^{1}H-NMR (300 MHz, $CDCl_3$): 0.93 (*t*, $^3J = 7.5$, Me); 2.31 (*m*, CH_2); 3.13 (*d*, $^2J = 17.7$, H_a–C(5)); 3.24 (*d*, $^2J = 17.7$, H_b–C(5)); 3.86 (*s*, MeO); 3.90 (*s*, MeO); 4.17 (*s*, H–C(1)); 5.99 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 12.9 (Me); 15.7 (CH_2); 32.9 (CH_2); 53.3 (MeO); 54.3 (CH); 55.7 (MeO), 83.6 (C(6)); 106.4 (C(3)); 119.0 (Cl_3C); 167.7 (C(4)); 172.5 (C=O); 189.0 (C=O). HR-ESI-MS: 345.0063 ($[M+H]^+$ (^{35}Cl), $C_{12}H_{16}Cl_3O_5^+$; calc. 345.0058).

*Ethyl (1*RS*,6*RS*)-6-Hydroxy-4-methoxy-2-oxo-3-pentyl-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4f**). From **1** (0.233 g, 1.0 mmol), *1-ethoxy-1,3-bis(trimethylsilyloxy)nona-1,3-diene* (**2n**; 0.693 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.268 g (70%). Slightly yellow oil. IR (ATR): 3433*w*, 2991*w*, 2961*w*, 2924*w*, 2855*w*, 1729*s*, 1647*s*, 1616*s*, 1446*m*, 1371*s*, 1333*s*, 1245*s*, 1217*s*, 1162*s*, 1120*s*, 1069*s*, 1025*s*, 929*m*, 909*s*, 794*s*, 647*s*, 591*s*, 557*m*, 444*m*, 429*m*. ^{1}H-NMR (300 MHz, $CDCl_3$): 0.87 (*t*, $^3J = 7.3$, Me); 1.26 – 1.39 (*m*, 3 CH_2, Me), 2.25 – 2.30 (*m*, CH_2); 3.13 (*d*, $^2J = 17.7$, H_a–C(5)); 3.25 (*d*, $^2J = 17.7$, H_b–C(5)); 3.90 (*s*, MeO); 4.13 (*s*, H–C(1)); 4.13 – 4.42 (*m*, CH_2); 6.13 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 13.9 (Me); 14.1 (Me); 22.3, 22.5, 28.0, 31.8, 32.9 (CH_2); 54.2 (MeO); 55.6 (C(1)); 62.6 (CH_2); 83.6 (C(6)); 106.5 (C(3)); 117.8 (Cl_3C); 167.8 (C(4)); 172.2 (C=O); 189.3 (C=O). HR-ESI-MS: 403.0660 ($[M+H]^+$ (^{35}Cl), $C_{16}H_{24}Cl_3O_5^+$; calc. 403.0657). Anal. calc. for $C_{16}H_{23}Cl_3O_5$ (401.71): C 47.84, H, 5.77; found: C 48.18, H 5.88.

*Methyl (1*RS*,6*RS*)-6-Hydroxy-4-methoxy-3-(3-methylbutyl)-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4g**). From **1** (0.233 g, 1.0 mmol), *1-methoxy-7-methyl-1,3-bis(trimethylsilyloxy)octa-1,3-diene* (**2f**; 0.689 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.126 g (33%). Slightly yellow oil. IR (ATR): 3432*w*, 2954*m*, 2928*m*, 2869*m*, 1735*m*, 1653*s*, 1623*m*, 1435*m*, 1366*m*, 1340*m*, 1246*m*, 1197*m*, 1164*s*, 1122*m*, 1102*m*, 1075*m*, 1039*m*, 1014*m,* 989*m*, 914*w*, 899*w*, 875*w*, 783*s*, 688*w*, 646*m*, 592*m*, 538*m*, 444*m*, 428*m*, 394*w*. ^{1}H-NMR (300 MHz, $CDCl_3$): 0.89 (*d*, $^3J = 6.6$, Me); 0.89 (*d*, $^3J = 6.6$, Me); 1.16 – 1.27 (*m*, CH_2); 1.44 – 1.57 (*m*, CH); 2.29 (*t*, $^3J = 6.7$, CH_2); 3.14 (*d*, $^2J = 17.6$, H_a–C(5)); 3.26 (*d*, $^2J = 17.6$, H_b–C(5)); 3.87 (*s*, MeO); 3.90 (*s*, MeO); 4.17 (*s*, H–C(1)); 6.00 (*s*, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): 20.6 (CH_2); 22.7, 22.8 (Me); 28.5 (CH); 33.2 (C(5)); 37.7 (CH_2); 53.6 (MeO); 54.6 (C(1)); 55.9 (MeO); 83.9 (C(6)); 106.6 (C(3)); 118.2 (Cl_3C); 168.1 (C(4)); 172.8, 189.4 (C=O). HR-ESI-MS: 387.0530 ($[M+H]^+$ (^{35}Cl), $C_{15}H_{22}Cl_3O_5^+$; calc. 387.0527).

*Ethyl (1*RS*,6*RS*)-3-Hexyl-6-hydroxy-4-methoxy-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4h**). From **1** (0.233 g, 1.0 mmol), *1-ethoxy-1,3-(trimethylsilyloxy)deca-1,3-diene* (**2o**; 0.717 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.219 g (53%). Slightly yellow oil. IR (ATR): 3433*w*, 2956*w*, 2923*w*, 2857*w*, 1730*s*, 1651*s*, 1621*s*, 1466*m*, 1372*s*, 1334*s*, 1280*m*, 1249*s*, 1216*m*, 1170*s*, 1027*s*, 1009*s*, 934*m*, 833*m*, 807*s*, 782*s*, 651*s*, 587*s*, 564*s*. ^{1}H-NMR (300 MHz, $CDCl_3$): 0.95 (*t*, $^3J = 7.8$, Me); 1.33 – 1.50 (*m*, 4 CH_2, Me), 2.16 – 2.21 (*m*, CH_2); 3.02 (*d*, $^2J = 17.6$, H_a–C(5)); 3.09 (*d*, $^2J = 17.7$, H_b–C(5)); 3.83 (*s*, MeO); 4.19 (*s*, H–C(1)); 4.21 – 4.40 (*m*, CH_2); 6.17 (br. *s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 14.2 (Me); 14.2 (Me); 22.3, 22.7, 28.3, 29.3, 31.7, 32.9 (CH_2); 54.2 (MeO); 55.6 (C(1)); 62.6 (CH_2); 83.6 (C(6)); 106.5 (C(3)); 117.8 (Cl_3C); 167.8 (C(4)); 172.2 (C=O); 189.3 (C=O). HR-ESI-MS: 415.0843 ($[M+H]^+$ (^{35}Cl), $C_{17}H_{26}Cl_3O_5^+$; calc. 415.0843).

*Methyl (1*RS*,6*RS*)-6-Hydroxy-4-methoxy-3-octyl-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4i**). From **1** (0.233 g, 1.0 mmol), *1-methoxy-1,3-bis(trimethylsilyloxy)dodeca-1,3-diene* (**2p**; 0.745 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.247 g (57%). Slightly yellow solid. M.p. 55 – 57°. IR (ATR): 3338*w*, 2954*w*, 2924*w*, 2854*w*, 1703*s*, 1651*m*, 1616*s*, 1374*s*, 1343*s*, 1164*s*, 1138*m*, 1114*m*, 981*m*, 916*m*, 805*s*, 674*s*, 605*s*, 592*s*, 541*s*, 439*s*, 393*w*. ^{1}H-NMR (300 MHz, $CDCl_3$): 0.87 (*t*, $^3J = 6.9$, Me); 1.25 – 1.31 (*m*, 6 CH_2); 2.28 (*t*, $^3J = 7.8$, CH_2); 3.13 (*d*, $^2J = 17.7$, H_a–C(5)); 3.26 (*d*, $^2J = 17.6$, H_b–C(5)); 3.87 (*s*, MeO); 3.90 (*s*, MeO); 4.17 (*s*, H–C(1)); 6.00 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 14.2 (Me); 22.3, 22.7, 28.3, 29.3, 29.5, 29.7, 31.9, 32.9 (CH_2); 53.3 (MeO), 54.3 (C(1)); 55.6

(MeO), 83.6 (C(6)); 106.4 (C(3)); 117.8 (Cl_3C); 167.8 (C(4)); 172.5, 189.1 (C=O). HR-ESI-MS: 429.0997 ($[M+H]^+$ (^{35}Cl), $C_{18}H_{28}Cl_3O_5^+$; calc. 429.0997). Anal. calc. for $C_{18}H_{27}Cl_3O_4$ (413.76): C 52.25, H 6.58; found: C 51.77, H 6.497.

*Methyl (1*RS,*6*RS*)-6-Hydroxy-4-methoxy-3-nonyl-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4j**). From **1** (0.233 g, 1.0 mmol), *1-methoxy-1,3-bis(trimethylsilyloxy)trideca-1,3-diene* (**2q**; 0.773 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.295 g (66%). Colorless solid. M.p. 69–71°. IR (ATR): 3342*w*, 2958*m*, 2919*m*, 2851*m*, 1703*m*, 1650*m*, 1616*s*, 1446*m*, 1436*m*, 1412*m*, 1374*m*, 1343*m*, 1277*w*, 1235*s*, 1201*m*, 1164*m*, 1137*m*, 1113*m*, 1088*m*, 1038*w*, 981*m*, 965*w*, 941*w*, 919*w*, 903*w*, 845*m*, 820*m*, 800*s*, 738*w*, 674*m*, 605*m*, 593*m*, 541*m*, 439*m*. ^{1}H-NMR (300 MHz, $CDCl_3$): 0.87 (*t*, $^3J = 6.5$, Me); 1.25–1.31 (*m*, 7 CH_2); 2.27 (*t*, $^3J = 6.3$, CH_2); 3.13 (*d*, $^2J = 17.6$, H_a–C(5)); 3.25 (*d*, $^2J = 17.6$, H_b–C(5)); 3.86 (*s*, MeO); 3.89 (*s*, MeO); 4.16 (*s*, H–C(1)); 5.99 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 14.5 (Me); 22.6, 23.0, 28.6, 29.6, 29.8, 29.9, 29.9, 30.0, 32.2, 33.2 (CH_2); 53.6 (MeO); 54.6 (C(1)); 55.9 (MeO); 83.9 (C(6)); 106.6 (C(3)); 118.1 (Cl_3C); 168.1 (C(4)); 172.8, 189.4 (C=O). HR-ESI-MS: 443.1157 ($[M+H]^+$ (^{35}Cl), $C_{19}H_{30}Cl_3O_5^+$; calc. 443.1153).

*Ethyl (1*RS,*6*RS*)-3-Decyl-6-hydroxy-4-methoxy-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4k**). From **1** (0.233 g, 1.0 mmol), *1-ethoxy-1,3-bis(trimethylsilyloxy)tetradeca-1,3-diene* (**2r**; 0.829 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.188 g (40%). Slightly yellow oil. IR (ATR): 3442*w*, 3032*w*, 2990*w*, 2955*w*, 2923*s*, 2855*s*, 1730*s*, 1642*m*, 1616*s*, 1445*m*, 1379*s*, 1331*s*, 1246*s*, 1218*m*, 1166*s*, 1144*m*, 1026*s*, 936*m*, 913*m*, 829*m*, 809*s*, 792*s*, 645*s*, 596*s*, 554*s*, 452*m*. ^{1}H-NMR (300 MHz, $CDCl_3$): 0.92 (*t*, $^3J = 6.9$, Me); 1.12–1.50 (*m*, 10 CH_2), 2.19 (*t*, $^3J = 8.9$, CH_2); 3.14 (*d*, $^2J = 17.7$, H_a–C(5)); 3.26 (*d*, $^2J = 17.7$, H_b–C(5)); 4.04 (*s*, MeO); 4.12 (*s*, H–C(1)); 6.17 (br. *s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 14.1 (Me); 14.2 (Me); 22.3, 22.7, 28.4, 28.4, 29.4, 29.4, 29.5, 29.5, 29.7, 32.0, 32.9 (CH_2); 54.2 (MeO); 55.6 (C(1)); 62.6 (MeO); 83.6 (C(6)); 106.5 (C(3)); 117.8 (Cl_3C); 167.8 (C(4)); 172.2, 189.3 (C=O). ESI-MS: 471.1471 ($[M+H]^+$ (^{35}Cl), $C_{21}H_{34}Cl_3O_5^+$; calc. 471.1466).

*Methyl (1*RS,*6*RS*)-3-Dodecyl-6-hydroxy-4-methoxy-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4l**). From **1** (0.233 g, 1.0 mmol), *1-methoxy-1,3-bis(trimethylsilyloxy)hexadeca-1,3-diene* (**2s**; 0.856 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.351 g (72%). Slightly yellow oil. IR (ATR): 3337*w*, 2920*s*, 2851*m*, 1702*m*, 1650*m*, 1614*s*, 1446*m*, 1436*m*, 1412*w*, 1375*m*, 1344*m*, 1277*w*, 1241*s*, 1165*m*, 1138*m*, 1115*m*, 1081*m*, 1048*m*, 981*m*, 959*w*, 919*m*, 902*w*, 878*w*, 849*m*, 832*m*, 804*s*, 737*w*, 720*w*, 671*m*, 604*m*, 593*m*, 537*m*, 438*m*, 395*w*. ^{1}H-NMR (300 MHz, $CDCl_3$): 0.88 (*t*, $^3J = 6.9$, Me); 1.25–1.30 (*m*, 10 CH_2), 2.28 (*t*, $^3J = 6.2$, CH_2); 3.14 (*d*, $^2J = 17.6$, H_a–C(5)); 3.26 (*d*, $^2J = 17.6$, H_b–C(5)); 3.87 (*s*, MeO); 3.90 (*s*, MeO); 4.17 (*s*, H–C(1)); 6.00 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 14.5 (Me); 22.6, 23.0, 28.6, 29.7, 29.8, 29.9, 30.0, 32.3, 33.2 (CH_2); 53.6 (MeO); 54.6 (C(1)); 55.9 (MeO); 83.9 (C(6)); 106.6 (C(3)); 118.1 (Cl_3C); 168.1 (C(4)); 172.8, 189.4 (C=O). HR-ESI-MS: 485.1623 ($[M+H]^+$ (^{35}Cl), $C_{22}H_{36}Cl_3O_5^+$; calc. 485.1623).

*Methyl (1*RS,*6*RS*)-3-Hexadecyl-6-hydroxy-4-methoxy-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4m**). From **1** (0.233 g, 1.0 mmol), *1-methoxy-1,3-bis(trimethylsilyloxy)icosa-1,3-diene* (**2t**; 0.936 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.346 g (64%). Yellow solid. M.p. 80–83°. IR (ATR): 3337*w*, 2918*s*, 2850*m*, 1702*m*, 1650*m*, 1614*s*, 1467*m*, 1447*m*, 1412*w*, 1376*m*, 1344*m*, 1277*w*, 1243*s*, 1202*m*, 1165*m*, 1139*m*, 1115*m*, 1088*m*, 1061*m*, 1039*m*, 977*m*, 958*w*, 920*m*, 902*w*, 879*w*, 845*m*, 828*m*, 804*s*, 738*w*, 720*m*, 671*m*, 604*m*, 594*m*, 538*m*, 438*m*. ^{1}H-NMR (300 MHz, $CDCl_3$): 0.88 (*t*, $^3J = 6.4$, Me); 1.25–1.30 (*m*, 14 CH_2), 2.28 (*t*, $^3J = 6.3$, CH_2); 3.14 (*d*, $^2J = 17.6$, H_a–C(5)); 3.26 (*d*, $^2J = 17.6$, H_b–C(5)); 3.87 (*s*, MeO); 3.90 (*s*, MeO); 4.17 (*s*, H–C(1)); 6.00 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 14.5 (Me); 22.6, 23.0, 29.7, 29.8, 30.0, 30.1, 32.3, 33.2 (CH_2); 53.6 (MeO); 54.6 (C(1)); 55.9 (MeO); 83.9 (C(6)); 106.6 (C(3)); 118.1 (Cl_3C); 168.1 (C(4)); 172.8, 189.4 (C=O). HR-ESI-MS: 541.2250 ($[M+H]^+$ (^{35}Cl), $C_{26}H_{44}Cl_3O_5^+$; calc. 541.2249).

*Methyl (1*RS,*6*RS*)-3-(3-Chloropropyl)-6-hydroxy-4-methoxy-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4n**). From **1** (0.233 g, 1.0 mmol), *7-chloro-1-methoxy-1,3-bis(trimethylsilyloxy)hepta-1,3-diene* (**2g**; 0.674 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.220 g (56%). Slightly yellow oil. IR (ATR): 3432*w*, 2994*w*, 2952*w*, 2876*w*, 2850*w*, 1719*s*, 1609*s*, 1435*m*, 1387*s*, 1247*s*, 1201*m*, 1666*s*, 1155*s*, 1128*m*, 1106*m*, 1060*s*, 997*m*, 959*m*, 830*s*, 798*s*, 648*s*, 593*s*, 560*s*, 466*m*, 430*m*, 397*w*. ^{1}H-NMR (300 MHz, $CDCl_3$): 1.82–1.89 (*m*, CH_2); 2.42–2.48 (*m*, CH_2); 3.17 (*d*, $^2J = 17.7$, H_a–C(5)); 3.29 (*d*, $^2J = 17.7$, H_b–C(5)); 3.49 (*t*, $^3J = 6.9$, CH_2); 3.93 (*s*, MeO); 3.94 (*s*, MeO); 4.19 (*s*,

H–C(1)); 5.98 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 19.9, 31.3, 32.9, 44.9 (CH_2); 53.4 (MeO); 54.3 (C(1)); 55.8 (MeO); 83.6 (C(6)); 106.2 (C(3)); 115.9 (Cl_3C); 168.8 (C(4)); 172.3, 189.1 (C=O). HR-ESI-MS: 392.9825 ($[M+H]^+$ (^{35}Cl), $C_{13}H_{17}Cl_4O_5^+$; calc. 392.9825). Anal. calc. for $C_{13}H_{16}Cl_4O_5$ (394.08): C 39.62, H 4.09; found: C 39.67, H, 4.127.

*Methyl (1*RS,*6*RS*)-3-(4-Chlorobutyl)-6-hydroxy-4-methoxy-2-oxo-6-(trichloromethyl)cyclohex-3-ene-1-carboxylate* (**4o**). From **1** (0.233 g, 1.0 mmol), *8-chloro-1-methoxy-1,3-bis(trimethylsilyloxy)octa-1,3-diene* (**2h**; 0.702 g, 2.0 mmol), and TMSOTf (0.18 ml, 1 mmol) in CH_2Cl_2 (2 ml). Yield: 0.310 g (76%). Slightly yellow solid. M.p. 56–58°. IR (ATR): 3383*w*, 2952*m*, 2859*w*, 1716*m*, 1654*m*, 1619*s*, 1436*m*, 1377*m*, 1342*m*, 1243*s*, 1168*s*, 798*s*, 649*m*, 598*m*, 435*m*, 392*m*. ^{1}H-NMR (300 MHz, $CDCl_3$): 1.44–1.54 (*m*, CH_2); 1.69–1.79 (*m*, CH_2); 2.33 (*t*, $^3J = 7.6$, CH_2); 3.15 (*d*, $^2J = 17.7$, H_a–C(5)); 3.27 (*d*, $^2J = 17.7$, H_b–C(5)); 3.53 (*t*, $^3J = 6.7$, CH_2); 3.87, 3.92 (*s*, MeO); 4.18 (*s*, H–C(1)); 5.98 (*s*, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): 21.3, 25.5, 32.3, 32.8, 45.0 (CH_2); 53.3 (MeO); 54.3 (C(1)); 55.7 (MeO); 83.6 (C(6)); 106.2 (C(3)); 116.8 (Cl_3C); 168.4 (C(4)); 172.4, 189.1 (C=O). Anal. calc. for $C_{14}H_{18}Cl_4O_5$ (408.10): C 41.20, H 4.45; found: C 41.46, H 4.47.

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