DOI: 10.1002/ejoc.200900687

Preparation of 2-Ethoxy-3-hydroxy-4-(perfluoroalkyl)tetrahydropyran Derivatives from Substituted 4-Ethoxybut-3-en-1-ols

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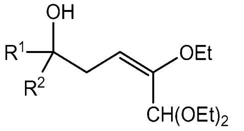
Keywords: Perfluoroalkylation / Carbohydrates / Enols

A number of 1-substituted and 1,1-disubstituted (*E*)-4,5,5-triethoxypent-3-en-1-ols (**1**) have been converted to perfluoroalkylated tetrahydrofurans and tetrahydropyrans in a selective fashion by 1-iodoperfluoroalkane addition under radical conditions using sodium dithionite ($Na_2S_2O_4$) as radical initiator. Direct perfluoroalkylation of **1** gave the former products only, and the yields were moderate (50–75 %), but when **1** was converted to corresponding 6-substituted and 6,6-disubstituted 2,3-diethoxy-5,6-dihydro-2*H*-pyrans before perfluoroalkylation was carried out, the transformation turned out to be significantly more successful and afforded, as the only product, 6-substituted and 6,6-disubstituted 2-ethoxy-4-(perfluoroalkyl)tetrahydropyran-3-ones in 77–100 % yield as stereoisomeric mixtures. Subsequent reduction of the keto group with sodium borohydride in ethanol was uneventful and completed the syntheses of a range of 4-perfluorobutylated tetrahydropyran derivatives; the yields in this step were in the 81–94 % range. The best result was obtained with (*E*)-2-methyl-5,6,6-triethoxyhex-4-en-2-ol which was converted to a diastereoisomeric mixture of 2-ethoxy-6,6-dimethyl-4-(perfluorobutyl)tetrahydropyran-3-ol in 85 % yield in three steps.

Introduction

Replacement of a hydrogen atom by a fluorine atom or a perfluoroalkyl group (R_F) in organic molecules may have a profound influence on their physical[1] and biological properties.[2] This is intimately related to the fact that fluorine is significantly more electronegative than hydrogen, has a mass which is 19 times that of hydrogen, and is about 30% larger.[3] In recent years these facts have triggered an increasing interest in the making of R_F-substituted organic molecules, including R_F-substituted carbohydrate derivatives,[3,4] which are expected to possess quite interesting properties with many potentially useful applications. Long hydrophobic and lipophobic perfluoroalkyl groups should make these derivatives useful as emulsifiers,[1] and the high gas-solvating ability of a number of perfluoroalkyl groups could make such R_F-substituted molecules important components in artificial blood.[2] The possibility of applying bioactive perfluoroalkylated molecules for in vivo ^{19}F-NMR spectroscopy and as liquid crystals is also an attractive idea.[1]

On this basis, we became interested in making modified carbohydrates with perfluoroalkyl substituents in various positions. In this paper, we present a novel strategy for the preparation of perfluoroalkylated tetrahydropyrans with one or two additional substituents attached to the ring. The synthetic approach involves perfluoroalkylation by addition of a perfluoroalkyl iodide (R_FI) to an alkene promoted by a radical initiator. Such reactions can be performed under a variety of conditions,[5–7] but we settled for a protocol applied successfully by Zhu and Li.[7] When their methodology was adopted we were able to develop reaction conditions that allowed selective conversion of 1-substituted (*E*)-4,5,5-triethoxypent-3-en-1-ol derivatives (**1**, Figure 1),[8] easily available from 3,3,4,4-tetraethoxybut-1-yne (TEB) as described in the literature,[9] to perfluoroalkylated derivatives of both tetrahydrofuran and tetrahydropyran.



1a $R^1 = R^2 = H$
1b $R^1 = Me, R^2 = H$
1c $R^1 = n\text{Hex}, R^2 = H$
1d $R^1 = Ph, R^2 = H$
1e $R^1 = R^2 = Me$
1f $R^1, R^2 = (CH_2)_5$

Figure 1. The hydroxylated vinyl ethers investigated.

Results and Discussion

Exploratory Experiments Based on 1a

In order to get an impression of the reactivity exhibited by vinyl ethers **1** under the reaction conditions employed by Zhu and Li,[7] various exploratory experiments were performed with the simplest representative of **1**, namely (*E*)-4,5,5-triethoxypent-3-en-1-ol (**1a**). Three interesting sets of

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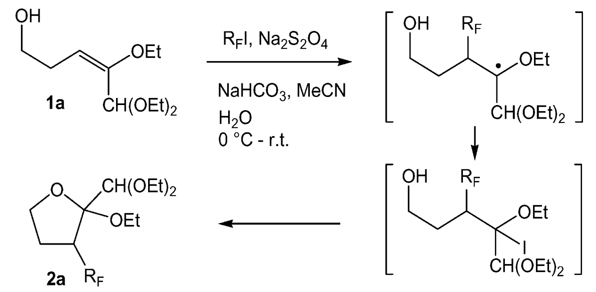
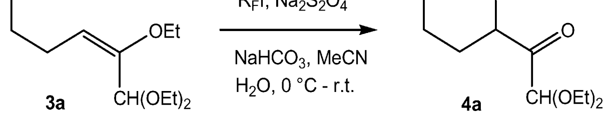
Supporting information for this article is available on the WWW under http://dx.doi.org/10.1002/ejoc.200900687.

results emerged. First and foremost, irrespective of the 1-iodoperfluoroalkane used, the final product was not any of the corresponding conceivable perfluoroalkylated iodides; instead a derivative of 2-(diethoxymethyl)-2-ethoxy-3-(perfluoroalkyl)tetrahydrofuran (**2a**) was obtained (Scheme 1). Secondly, the yield of **2a** appeared to vary with the length of the perfluoroalkyl chain; the longer the chain the lower the yield (which dropped from 75% to 51% when the number of carbon atoms increased from 4 to 8). And finally, irrespective of the size of R_f group the tetrahydrofurans were formed as 1.0:1.0 mixtures of the *cis* and *trans* isomers, which indicates that the product formed is kinetically controlled.



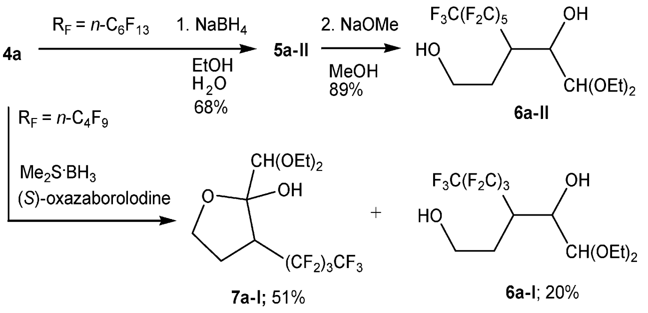
Scheme 1. Addition of 1-iodoperfluoroalkanes to alcohol **1a**; **2a-I** (R_F = n-C_4F_9), **2a-II** (R_F = n-C_6F_{13}), and **2a-III** (R_F = n-C_8F_{17}) were obtained in 75, 59 and 51% yield, respectively.

As indicated in Scheme 1 the primary products were conceivably the expected iodides (formed via the most stable radical),[5,6] which suffered intramolecular substitution and gave tetrahydrofuran **2a**. In order to prevent this from happening protection of the hydroxy group was apparently required. Treatment of **1a** with acetyl chloride, triethylamine, and DMAP gave the corresponding acetate, (*E*)-4,5,5-triethoxypent-3-enyl acetate (**3a**), in 86% yield, and when this ester was exposed to 1-iodoperfluorobutane and 1-iodoperfluorohexane in the presence of sodium dithionite, the expected acyclic 3-perfluoroalkyl-substituted 5,5-diethoxy-4-oxopentyl acetates, **4a-I** and **4a-II**, respectively, were isolated (Scheme 2). Again the yield depends on the length of the carbon chain of R_FI, but in this case the addition reaction was most successful when the iodoperfluoroalkane with the higher number of carbon atoms was used.



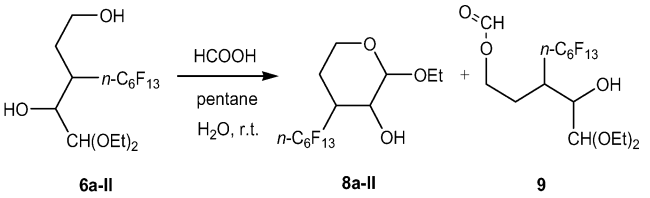
Scheme 2. Addition of 1-iodoperfluoroalkanes to acetate **3a**; **4a-I** (R_F = n-C_4F_9) and **4a-II** (R_F = n-C_6F_{13}) were obtained in 61 and 76% yield, respectively.

Deprotection of the hydroxy group is necessary to achieve cyclization and when this transformation was carried out under neutral or acidic aqueous conditions several products, including tetrahydrofuran **2a**, were formed. In order to prevent formation of the latter, the keto moiety of **4a** has to be reduced before the ester protection of the OH group is removed. This approach worked well when **4a-II** was reacted first with sodium borohydride [to give 5,5-diethoxy-4-hydroxy-3-(perfluorohexyl)pentyl acetate (**5a-II**)] and then with sodium methoxide in methanol; in this way 5,5-diethoxy-3-(perfluorohexyl)pentane-1,4-diol (**6a-II**) was obtained in quite respectable yield (Scheme 3). However, attempts to perform chiral reduction, with mixtures of the borane–dimethyl sulfide complex and (*S*)-oxazaborolidine,[10] were far less successful; for instance, when **4a-I** was reduced with this reagent 5,5-diethoxy-3-(perfluorobutyl)-pentane-1,4-diol (**6a-I**) was formed directly, but the yield was low (20%) and the main product was the undesired tetrahydrofuran-2-ol **7a-I**, which was obtained in 51% yield (Scheme 3).



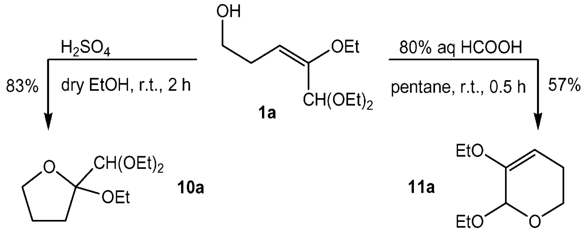
Scheme 3. Reduction of **4a-I** and **4a-II** under different conditions.

Diols **6a** were expected to form tetrahydropyran derivatives under acidic conditions, and that appeared indeed to be the case, albeit the yields were moderate to low due to formation of undesired products or unidentified by-products under all the reaction conditions applied. The results from treatment of **6a-II** with 80% aqueous formic acid in pentane are representative; tetrahydropyran **8a-II** was isolated in 40% yield as an isomeric mixture, along with the predominant product, formate **9**, which was isolated in 52% yield (Scheme 4).



Scheme 4. Attempted synthesis of the corresponding tetrahydropyran from diol **6a-II**.

The results presented above show that 4-perfluoroalkylated deoxygenated tetrahydropyran derivatives of type **8a** can be obtained from vinyl ether **1a**, but the number of steps is high (six) and the overall yield is low (in the case of **8a-I** only 15%). Since two of the steps are associated with protection/deprotection to avoid tetrahydrofuran formation, it is apparent that it would be attractive if the hydroxy group in **1** could be protected through a cyclization reaction analogous to the transformation, which ultimately is required in any case to achieve ring formation. Such an alternative approach would amount to converting **1** into the corresponding dihydropyran derivative *before* perfluoroalkylation was carried out, and this ring formation did indeed occur with **1a** under acidic conditions. However, the efficiency of the reaction and the product yield were sensitive to the reagent used (see Scheme 5); thus, when sulfuric acid or an ion-exchange resin (Dowex 50W) was used as catalyst, the desired reaction did not occur, instead 2-ethoxy-2-(diethoxymethyl)tetrahydrofuran (**10a**) was obtained in good yield. Switching to silica-gel catalysis in ethanol or ethyl acetate, however, gave 2,3-diethoxy-5,6-dihydro-2*H*-pyran (**11a**), but the reaction was very sluggish and stirring at 80 °C for more than 100 h was required to obtain the compound in better than 60% yield. Finally, a two-phase system, with formic acid as catalyst, was tried, and these conditions appeared overall to be the best, giving **11a** in 57% isolated yield after a reaction time of only 30 min.



Scheme 5. Acid-catalyzed intramolecular cyclization of **1a**.

With dihydropyranyl vinyl ether **11a** at hand 1-iodoperfluoroalkane addition was performed.[7] All three iodides used gave the corresponding addition product, 2-ethoxy-4-(perfluoroalkyl)tetrahydropyran-3-one (**12a**), as a pure sample of an approximately 1:1 mixture of the *cis* and *trans* isomers in good to excellent yield. Just like perfluoroalkylation of **1a**, vinyl ether **11a** appeared to afford the corresponding addition product **12a** in yields decreasing with increasing length of the perfluoroalkyl chain (see Figure 2). The isomer composition of the compounds was clearly reflected in their proton and carbon NMR spectra, which exhibited both separate and overlapping peaks for the isomers. By NOESY experiments some of the separate peaks due to the individual isomers could be used to determine the configuration of the perfluoroalkyl groups relative to the ethoxy group, and from the integrals in the proton spectra, the *cis*/*trans* composition was determined to be 44:56 for **12a-I**, 52:48 for **12a-II**, and 38:62 for **12a-III**.

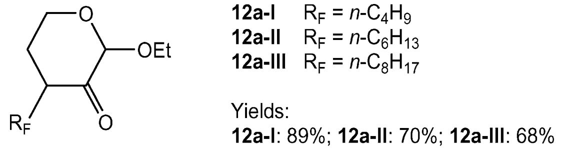
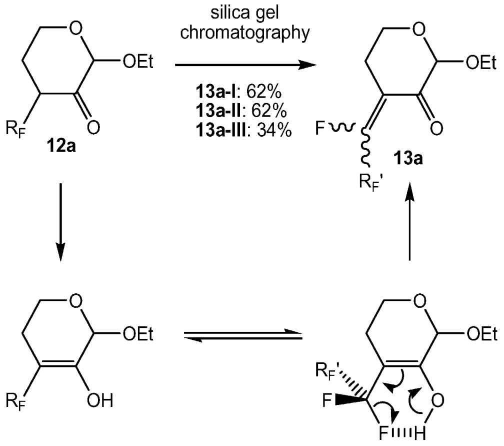


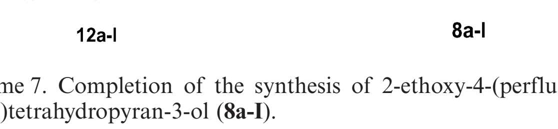
Figure 2. The 2-ethoxy-4-(perfluoroalkyl)tetrahydropyran-3-ones (**12a**) prepared from **11a**.

Several attempts were made to separate the *cis* and *trans* isomers of **12a-I**, **12a-II**, and **12a-III** by flash chromatography, but all efforts failed irrespective of the conditions applied. An indication that such a failure was about to occur was indeed observed when the product mixtures were analyzed by TLC (to work out the flash-chromatographic conditions) and only one spot was observed regardless of the eluent used. And indeed, when each mixture of the isomeric tetrahydropyranones was flashed on a silica-gel column with a gradient going from a 5:95 to a 10:90 mixture of ethyl acetate and hexanes as eluent, decomposition occurred and gave in each case one isolable product, which, on the basis of spectroscopic and spectrometric analyses, was the 4-perfluoroalkylidene analogue of **12a**, namely **13a** (Scheme 6). Spectroscopic data indicated that **13a** in each case was obtained as an approximate 4:1 mixture of the *E* and the *Z* isomers, but the configuration of the predominant isomer has still not been settled. However, according to Huang et al. hydrogen bonding between the fluorine atoms of the CF_2 group attached to the ring and the neighbouring hydroxy group generated by enolization is a stabilizing interaction,[11] which should favour subsequent hydrogen fluoride elimination as depicted in Scheme 6. This line of reasoning is supported by the fact that a similar elimination reaction was observed by Miura et al. when they carried out perfluoroalkylation of a number of trimethylsilyl vinyl ethers, e.g., 1-trimethylsiloxy-1-cyclohexene.[6]



Scheme 6. HF elimination from **12a**, facilitated by enolization and hydrogen bonding.

Reduction of **12a** with sodium borohydride constitutes the last step in the alternative synthesis of **8a**, and when this reaction was performed with a *cis*/*trans* isomeric mixture of 2-ethoxy-4-(perfluorobutyl)tetrahydropyran-3-one (**12a-I**) (ratio 44:56), alcohol **8a-I** was obtained in 94% yield (as a mixture of diastereoisomers, vide infra) (Scheme 7). Consequently, the alternative strategy is significantly more attractive than the first stepwise synthesis investigated; not only is

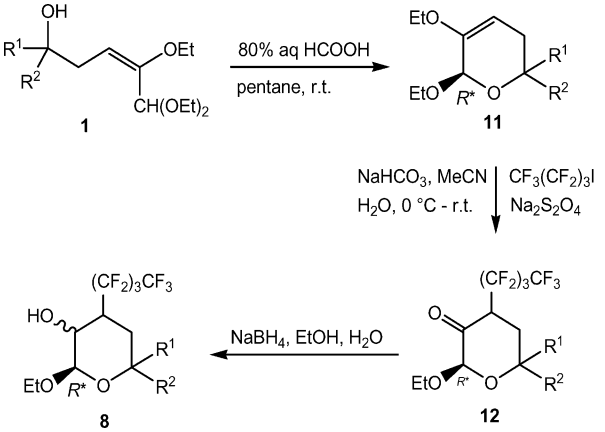


Scheme 7. Completion of the synthesis of 2-ethoxy-4-(perfluorobutyl)tetrahydropyran-3-ol (**8a-I**).

the number of steps reduced from six to three, the overall yield for the conversion of **1a** to **8a** has also more than tripled (from 15–50 %).

Synthesis of Analogues to 8a from 1b–1f

The latter synthetic route to **8a** (Scheme 8) was then applied to make 4-perfluoroalkylated tetrahydropyrans from vinyl ethers **1b** – **1f**, which in fact are available from TEB in better yields than **1a**.[8] Since perfluoroalkylation of **11a** was most successful when 1-iodoperfluorobutane was used, this was the only iodide employed in the investigation of perfluoroalkylation of **11b**–**11f**.



Scheme 8. The synthesis of 4-perfluoroalkyl-substituted deoxycarbohydrate analogues **8** from homoallylic alcohols **1**. Position 2 in the ring is arbitrarily shown with *R* configuration as a point of reference.

Treatment of a pentane solution of alcohols **1b**–**1f** with formic acid in water or ethanol afforded the corresponding 6-substituted 2,3-diethoxy-5,6-dihydro-2*H*-pyrans **11b**–**11f** in variable yields. In order to obtain as good yields as possible the alcohols (prepared from the corresponding 1-substituted 4,4,5,5-tetraethoxy-2-pentyn-1-ols as described in the literature[8]) were not purified before cyclization was carried out. This measure improved the yield in some cases, and as the results compiled in Table 1 show, the pyrans were obtained in respectable to excellent yields. Since alcohols **1b**–**1d** are chiral it was expected that **11b**–**11d** would be formed as mixtures of *cis* and *trans* isomers, and that was indeed observed. Pure samples of all the isomers were obtained by flash chromatography and that paved the way for unambiguous determination of their structures and thus the *cis*/*trans* ratios. As the results in Table 1 show the ratio is quite sensitive to the nature of the substituent attached to the chiral centre of **1**, but no general conclusion can be drawn regarding this sensitivity on the basis of this limited body of data.

With pure samples of the racemates of pyrans **11e** and **11f** as well as the *cis* and *trans* isomers of **11b**–**11d** available, 1-iodoperfluorobutylation was carried out according to the procedure for 1-iodoperfluoroalkylation of **11a** (see Experimental Section). All the reactions turned out to be very efficient, and the corresponding 6-substituted 2-ethoxy-4-(perfluorobutyl)tetrahydropyran-3-ones (**12-I**) were in most cases obtained in excellent yield (Table 2). All the 3-pyranones were obtained essentially pure as isomeric mixtures without performing any special purification step(s). However, the isomer composition of the compounds could be worked out by using their ^{1}H- and ^{13}C-NMR spectra, which contained both separate and overlapping peaks for the different isomers. By using the signals due to the individual isomers in the proton spectra of **12b-I**–**12f-I**, NOESY experiments and other 2D techniques were used to determine the configuration of the perfluorobutyl group relative to the ethoxy group for every 3-tetrahydropyranone. The integrals of the separate signals were subsequently utilized to determine the isomer composition.

The results incorporated in Table 2 show that the stereoselectivity of the perfluorobutylation was insignificant, which is not surprising when molecular models of **11** are inspected and reveal that it is unlikely that any conformation should be particularly stable and therefore predominate. However, it is interesting to note that the highest selectivity is observed when **11e** and **11f** are reacted; both of

Table 1. Formation of 2,3-diethoxy-5,6-dihydro-2*H*-pyrans substituted in position 6 (**11a**–**11f**) from allylic alcohols **1a**–**1f** as outlined in Scheme 7.

Alcohol cyclized[a]	R^1, R^2	Product/overall yield[b]	Yield cyclization[c]	*cis*/*trans* ratio[d]
1a	H, H	**11a**/40 %	57 %	n.r.[e]
1b	H, Me	**11b**/52 %	70 %	27:73
1c	H, *n*-Hex	**11c**/49 %	53 %	38:62
1d	H, Ph	**11d**/61 %	85 %	68:32
1e	Me, Me	**11e**/55 %	100 %	n.r.[e]
1f	$-(CH_2)_5-$	**11f**/76 %	–	n.r.[e]

[a] The alcohols, prepared from the corresponding 1-substituted 4,4,5,5-tetraethoxy-2-pentyn-1-ols as described in the literature,[8] were not purified before cyclization was carried out. [b] The yield of **11** from the corresponding 1-substituted 4,4,5,5-tetraethoxy-2-pentyn-1-ol. [c] The yield for the cyclization reaction, calculated from the overall yield and the yield published for formation of **1** from the corresponding 1-substituted 4,4,5,5-tetraethoxy-2-pentyn-1-ols.[8] The yield of **1f** from 1-(3,3,4,4-tetraethoxybut-1-ynyl)cyclohexanol is not available. [d] With reference to Scheme 8, where the configuration of position 2 has arbitrarily been chosen to be *R*, the *cis* isomers of **11b** and **11c** have the 2*R**,6*R** configuration, whereas the *cis* isomer of **11d** has the 2*R**,6*S** configuration. Consequently, the *trans* isomers of **11b** and **11c** have the 2*R**,6*S** configuration, whereas the *trans* isomer of **11d** has the 2*R**,6*R** configuration. [e] n.r.: not relevant.

Table 2. Formation of 6-substituted 2-ethoxy-4-(perfluorobutyl)-tetrahydropyran-3-ones (**12-I**) by 1-iodoperfluorobutylation of 6-substituted 2,3-diethoxy-5,6-dihydro-2*H*-pyrans (**11a**–**11f**) under the conditions shown in Scheme 7.

Substrate[a]	Product [b]	Yield	4*R**/4*S**[c]
(2*R**)-**11a**	(2*R**,4*R**/4*S**)-**12a-I**	89%	56:44
(2*R**,6*R**)-**11b**	(2*R**,4*R**/4*S**,6*R**)-**12b-I**	78%	42:58
(2*R**,6*S**)-**11b**	(2*R**,4*R**/4*S**,6*S**)-**12b-I**	99%	60:40
(2*R**,6*R**)-**11c**	(2*R**,4*R**/4*S**,6*R**)-**12c-I**	77%	55:45
(2*R**,6*S**)-**11c**	(2*R**,4*R**/4*S**,6*S**)-**12c-I**	86%	65:35
(2*R**,6*S**)-**11d**	(2*R**,4*R**/4*S**,6*S**)-**12d-I**	95%	50:50
(2*R**,6*R**)-**11d**	(2*R**,4*R**/4*S**,6*R**)-**12d-I**	93%	70:30
(2*R**)-**11e**	(2*R**,4*R**/4*S**)-**12e-I**	96%	84:16
(2*R**)-**11f**	(2*R**,4*R**/4*S**)-**12f-I**	91%	80:20

[a] With reference to Scheme 7 and Scheme 8, where position 2 arbitrarily has been given the *R* configuration, the configuration of **11a**, **11e** and **11f** becomes 2*R** whereas the *cis* isomers of **11b** and **11c** have the 2*R**,6*R** configuration and the *cis* isomer of **11d** has the 2*R**,6*S** configuration. Similarly, the *trans* isomers of **11b** and **11c** have the 2*R**,6*S** configuration whereas the *trans* isomer of **11d** has the 2*R**,6*R** configuration. [b] The 4*S** configuration corresponds to a *cis* relationship between the ethoxy and the perfluorobutyl groups, the 4*R** to a *trans* relationship. [c] The isomeric composition was determined by means of the integrals in the ^{1}H NMR spectra of the crude products, recorded before the final work-up was carried out.

these substrates have a symmetrically disubstituted carbon atom in position 6, a consequence of which may be that the reaction is influenced by conformational effects caused by some sort of *gem*-dimethyl or Thorpe–Ingold effect.[12]

In order to complete the syntheses of the 6-substituted 4-(perfluorobutyl)carbohydrate analogues to **8a-I**, the isomeric mixtures of 2-ethoxy-4-(perfluorobutyl)tetrahydropyran-3-ones **12b-I** to **12f-I** were treated with sodium borohydride in aqueous ethanol as described for **12a-I**. Reduction under these conditions appeared to give the corresponding 4-tetrahydropyranols in very good to excellent yields (Table 3). Unlike the perfluoroalkylation, the reduction occurs with significant stereoselectivity and give mainly, in two cases (6*R**)**-8d-I** and 6*S**)**-8d-I**) even exclusively, 3-tetrahydropyranols with a *cis* relationship between the hydroxy and ethoxy groups, which corresponds to a 2*R**,3*S** configuration (see Table 3). Apparently the ethoxy moiety influences the borohydride attack quite considerably so that the hydride approach from the *Re* face is rendered more favourable than that from the *Si* face.

Conclusions

A high-yield synthesis of 2-ethoxy-4-(perfluorobutyl)-tetrahydropyran-3-ols substituted at position 6 from simple starting materials has been developed. Overall the best result was obtained with (*E*)-2-methyl-5,6,6-triethoxyhex-4-en-2-ol which was obtained from acetone and 3,3,4,4-tetraethoxybutyne (TEB) and then converted to a diastereoisomeric mixture of 2-ethoxy-6,6-dimethyl-4-(perfluorobutyl)-tetrahydropyran-3-ol in 85% yield in three steps. Thus, a new group of modified carbohydrates has become easily available, and studies of their chemical potential as well as physical and biological properties are about to begin.

Experimental Section

General: Diethyl ether and THF were distilled from sodium/benzophenone prior to use in reactions under an inert atmosphere. All other solvents used in reactions were anhydrous grade and used as received. Solvents used for extractions and flash chromatography were technical grade. All reagents were used as received. Reactions carried out under an inert atmosphere were performed under N_2. Flash column chromatography was carried out using Merck 60 Kieselgel (230–400 mesh) with mixtures of hexane/ethyl acetate as the mobile phase. Analytical thin-layer chromatography (TLC) was performed on plates precoated with Merck Kieselgel 60 F254, and visualized by ultraviolet irradiation (254 nm) or by staining with aqueous acidic ammonium hexamolybdate, aqueous acidic potassium permanganate or ethanolic acidic phosphomolybdic acid solutions as appropriate. Boiling points and melting points are uncorrected. Melting points were performed on a Reichert hot-stage or a Gallenkamp apparatus. Infrared spectra were obtained with a Nicolet impact 410 spectrometer with the samples either as a film between two NaCl plates or as a solid in KBr discs. Absorptions are given in wavenumbers (cm^{-1}) and intensities are given as strong (s), medium (m), weak (w), and broad (br). Mass spectra and accurate mass data were obtained with a VG 7070 Micromass spectrometer and an Autospec Ultima GC-MS from Micromass Ltd., both

Table 3. Formation of 6-substituted 2-ethoxy-4-(perfluorobutyl)tetrahydropyran-3-ols (**8-I**) by treating 6-substituted 2-ethoxy-4-(perfluorobutyl)tetrahydropyran-3-ones **12a-I** to **12f-I** with $NaBH_4$ in aqueous ethanol.

Substrate[a]	Product	Yield	3*S**/4*R**:3*S**/4*S**:3*R**/4*R**,3*R**/4*S**[b]	(*cis*-OH):(*trans*-OH)[c]
(2*R**,4*R**/4*S**)-**12a-I**	(2*R**,3*R**/3*S**,4*R**/4*S**)-**8a-I**	94%	34:33:22:11	67:33
(2*R**,4*R**/4*S**,6*R**)-**12b-I**	(2*R**,3*R**/3*S**,4*R**/4*S**,6*R**)-**8b-I**	81%	42:48:0:10	90:10
(2*R**,4*R**/4*S**,6*S**)-**12b-I**	(2*R**,3*R**/3*S**,4*R**/4*S**,6*S**)-**8b-I**	93%	76:12:8:4	88:12
(2*R**,4*R**/4*S**,6*R**)-**12c-I**	(2*R**,3*R**/3*S**,4*R**/4*S**,6*R**)-**8c-I**	86%	50:27:5:18	77:23
(2*R**,4*R**/4*S**,6*S**)-**12c-I**	(2*R**,3*R**/3*S**,4*R**/4*S**,6*S**)-**8c-I**	92%	55:35:10:0	90:10
(2*R**,4*R**/4*S**,6*S**)-**12d-I**	(2*R**,3*R**/3*S**,4*R**/4*S**,6*S**)-**8d-I**	87%	22:78:0:0	100:0
(2*R**,4*R**/4*S**,6*R**)-**12d-I**	(2*R**,3*R**/3*S**,4*R**/4*S**,6*R**)-**8d-I**	84%	78:22:0:0	100:0
(2*R**,4*R**/4*S**)-**12e-I**	(2*R**,3*R**/3*S**,4*R**/4*S**)-**8e-I**	89%	73:12:11:4	85:15
(2*R**,4*R**/4*S**)-**12f-I**	(2*R**,3*R**/3*S**,4*R**/4*S**)-**8f-I**	88%	80:17:0:3	97:3

[a] For each substrate the 4*R**/4*S** ratio was that given in Table 2. [b] The ratios were determined by ^{1}H NMR spectroscopy. [c] The terms *cis*-OH and *trans*-OH are used to indicate the position of the OH group relative to ethoxy substituents. The *cis* relationship corresponds to a 2*R**,3*S** configuration whereas a *trans* relationship corresponds to a 2*R**,3*R** configuration.

operated in the EI mode at 70 eV. The spectra are reported as *m*/*z* (% relative intensity). ^{1}H NMR spectra were recorded at ambient temperature either with a Bruker Spectrospin AC 200 F instrument at 200 MHz or a Bruker Spectrospin DMX 400 spectrometer at 400 MHz with residual protic solvent $CHCl_3$ (δ_H = 7.25 ppm) or TMS (δ_H = 0.00 ppm) as the internal reference. ^{19}F NMR spectra were recorded at ambient temperature with the DMX 400 at 373 MHz. Chemical shifts in fluorine spectra are reported relative to $CFCl_3$ (δ_F = 0.00 ppm). Chemical shifts are reported downfield from the reference standard and coupling constants are given in Hz. Multiplicity is given as singlet (s), doublet (d), triplet (t), quartet (q), double doublet (dd), double triplet (dt), and multiplet (m), and wide signals are denoted broad (br). The proton and fluorine spectra are reported as follows: δ/ppm (number of protons/fluorine, multiplicity, coupling constant *J*/Hz). ^{13}C NMR spectra were recorded at ambient temperatures on the same spectrometers at 50 MHz or 100 MHz, with the central peak of $CHCl_3$ as the internal reference (δ_C = 77.0 ppm). DEPT-135 were used where appropriate, to aid the assignment of signals in the ^{13}C NMR spectra. Where coincident coupling constants have been observed in the ^{1}H NMR spectrum, the apparent multiplicity of the proton resonance concerned has been reported. COSY, HSQC and HMBC was used to aid the structural assignment of the products and NOESY was used to decide the relative stereochemistry in the products.

Synthesis of Vinyl Ethers 1: The syntheses of **1a**–**1e** have been described in the literature.[8] The same procedure was employed to prepare 1-[(*E*)-4,5,5-triethoxybut-2-enyl]cyclohexanol (**1f**) from 1-(3,3,4,4-tetraethoxybut-1-ynyl)cyclohexanol which was prepared from TEB (23.0 g, 0.10 mmol) and cyclohexanone (10.8 g, 0.11 mmol). When EtMgBr was used to generate the acetylide,[8] 1-(3,3,4,4-tetraethoxybut-1-ynyl)cyclohexanol was obtained as a yellowish liquid in 79% yield (24.9 g) after isolation by flash chromatography (hexane/ethyl acetate in a 80:20 ratio). IR (film): $\tilde{\nu}_{max}$ = 3418 (m), 2975 (s), 2933 (s), 2237 (w), 1447 (m), 1387 (m), 1335 (m), 1260 (m), 1235 (m), 1079 (s), 968 (m), 901 (w), 790 (w), 736 (w) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.38 [s, 1 H, $CH(OEt)_2$], 3.88–3.65 (m, 8 H, 4 CH_2 of 4 OEt), 3.32 (br. s, 1 H, OH), 1.99–1.94 (m, 2 H, 2 cyclohexyl H), 1.74–1.55 (m, 8 H, 8 cyclohexyl H), 1.23 (t, $^3J_{H,H}$ = 7.0 Hz, 6 H, 2 CH_3 groups of 2 OEt groups), 1.21 (t, $^3J_{H,H}$ = 7.0 Hz, 6 H, 2 CH_3 groups of 2 OEt groups) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 103.8 (CH), 98.5 (C), 90.9 (C), 78.6 (C), 68.1 (C), 64.0 (2 × CH_2), 59.5 (2 × CH_2), 39.5 (2 × CH_2), 24.9 (CH_2), 23.0 (2 × CH_2), 15.1 (2 × CH_3), 15.0 (2 × CH_3) ppm. MS (EI): *m*/*z* (%) = 327 (1), 311 (12), 299 (15), 282 (81), 253 (49), 238 (73), 227 (62), 208 (71), 181 (72), 164 (78), 151 (85), 133 (72), 111 (86), 97 (100), 82 (92), 57 (86). HRMS: *m*/*z* calcd. for $C_{18}H_{32}O_5$ [M^+] 328.2250; found 328.2247. Vinyl ether **1f** was prepared from 1-(3,3,4,4-tetraethoxybut-1-ynyl)cyclohexanol following a literature procedure, but the sample was used in 1-iodo-perfluorobutylation without being properly purified. IR (film): $\tilde{\nu}_{max}$ = 3451 (s), 2973 (s), 2929 (s), 1661 (m), 1447 (m), 1386 (m), 1343 (m), 1297 (m), 1263 (m), 1071 (s), 988 (m), 885 (m), 853 (m), 731 (w), 688 (w) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 5.02 [s, 1 H, $CH(OEt)_2$], 4.67 (t, $^3J_{H,H}$ = 8.5 Hz, 1 H, HC=), 3.79–2.43 (m, 6 H, 3 CH_2 from 3 OEt), 2.44 (br. s, 1 H, O-H), 2.33 (d, $^3J_{H,H}$ = 8.5 Hz, 2 H, CH_2C=), 1.70–1.40 (m, 10 H, 10 cyclohexyl H), 1.35–1.23 (m, 9 H, 3 CH_3 of 3 OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 149.3 (C), 93.4 (CH), 92.0 (CH), 71.9 (C), 62.6 (CH_2), 61.6 (2 × CH_2), 37.2 (2 × CH_2), 34.6 (CH_2), 25.2 (CH_2), 21.6 (CH_2), 21.5 (CH_2), 14.2 (2 × CH_3), 13.6 (CH_3) ppm. MS (EI): *m*/*z* (%) = 240 (30), 195 (93), 167 (41), 149 (72), 137 (68), 121 (62), 113 (100), 95 (57), 81 (73). HRMS: *m*/*z* calcd. for $C_{14}H_{25}O_3$, [M – OEt]$^+$ 241.1804; found 241.1804.

Investigations Based on 1a

General Procedure for Perfluoroalkylation of 1a; Formation of 2a: The procedure is based on a protocol published by Zhu and Li.[7] To a solution of vinyl ether **1a** (0.22 g, 1.0 mmol), CH_3CN (1.2 mL), water (1.0 mL) and 1-iodoperfluoroalkane (1.3 mmol) at 0 °C (for perfluorooctyl iodide a 20 °C water bath was used) under N_2 were added $NaHCO_3$ (0.11 g, 1.3 mmol) and sodium dithionite ($Na_2S_2O_4$) (0.23 g, 1.3 mmol). The resulting solution was stirred overnight; H_2O was then added, and the hydrolysate was extracted with DCM. The combined organic extracts were dried with $MgSO_4$, filtered, and evaporated on a rotary evaporator until the solvents were removed and a pure residue was left behind.

2-(Diethoxymethyl)-2-ethoxy-3-(perfluorobutyl)tetrahydrofuran (2a-I): The product, 0.33 g (75% yield), was obtained as a clear liquid. IR (film): $\tilde{\nu}_{max}$ = 2980 (s), 2898 (s), 1452 (m), 1382 (m), 1352 (s), 1227 (s), 1133 (s), 1072 (s), 940 (m), 907 (m), 800 (m), 727 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.63 and 4.62 [2s in a 1.0:1.0 ratio, 1 H, $CH(OEt)_2$], 4.16–3.97 (m, 2 H, 5-H), 3.92–3.51 (m, 6 H, 3 CH_2 of 3 OEt), 3.39–3.16 (m, 1 H, 3-H), 2.37–2.15 (m, 2 H, 4-H), 1.29–1.12 (m, 9 H, 3 CH_3 of 3 OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 107.5 (C), 103.4 and 103.3 (CH), 67.3 (CH_2), 65.7 (CH_2), 63.7 (CH_2), 58.1 (CH_2), 44.3 (t, *J* = 20.5 Hz, CH), 25.0 (CH_2), 15.7 (CH_3), 15.4 (CH_3), 15.0 (CH_3) ppm. MS (EI): *m*/*z* (%) = 391 (10), 333 (68), 305 (100), 289 (25), 195 (8), 103 (92), 91 (11), 75 (46). HRMS: *m*/*z* calcd. for $C_{13}H_{16}F_9O_3$ ([M – OEt]$^+$) 391.0956; found 391.0962.

2-(Diethoxymethyl)-2-ethoxy-3-(perfluorohexyl)tetrahydrofuran (2a-II): The compound, 0.33 g (59% yield), was obtained as a clear liquid. IR (film): $\tilde{\nu}_{max}$ = 2981 (s), 2934 (s), 2900 (S), 1453 (w), 1362 (m), 1239 (s), 1202 (s), 1146 (s), 1073 (s), 967 (w), 892 (w), 797 (w), 737 (m), 711 (m), 655 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.63 and 4.62 [2s in a 1.0:1.0 ratio, 1 H, $CH(OEt)_2$], 4.15–3.96 (m, 2 H, 5-H), 3.91–3.51 (m, 6 H, 3 CH_2 of 3 OEt), 3.39–3.16 (m, 1 H, 3-H), 2.37–2.14 (m, 2 H, 4-H), 1.29–1.12 (m, 9 H, 3 CH_3 of 3 OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 107.6 (C), 103.4 and 103.3 (CH), 67.3 (CH_2), 65.7 (CH_2), 63.8 (CH_2), 58.2 (CH_2), 44.4 (t, *J* = 20.3 Hz, CH), 25.1 (CH_2), 15.8 (CH_3), 15.4 (CH_3), 15.0 (CH_3) ppm. MS (EI): *m*/*z* (%) = 491 (10), 433 (66), 405 (92), 389 (24), 369 (6), 341 (11), 121 (7), 103 (100), 91 (17), 75 (52). HRMS: *m*/*z* calcd. for $C_{15}H_{16}F_{13}O_3$, ([M – OEt]$^+$) 491.0892; found 491.0893.

2-(Diethoxymethyl)-2-ethoxy-3-(perfluorooctyl)tetrahydrofuran (2a-III): The compound, 0.32 g (51% yield), was obtained as a clear liquid. IR (film): $\tilde{\nu}_{max}$ = 2982 (s), 2901 (s), 2934 (s), 1453 (w), 1368 (m), 1323 (m), 1211 (s), 1149 (s), 1073 (s), 897 (w), 807 (w), 778 (w), 724 (m), 712 (m), 657 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.62 and 4.63 [2s in a 1.0:1.0 ratio, 1 H, $CH(OEt)_2$], 4.15–3.96 (m, 2 H, 5-H), 3.91–3.51 (m, 6 H, 3 CH_2 of 3 OEt), 3.39–3.16 (m, 1 H, 3-H), 2.37–2.13 (m, 2 H, 4-H), 1.29–1.11 (m, 9 H, 3 CH_3 of 3 OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 107.6 (C), 103.5 and 103.4 (CH), 67.3 (CH_2), 65.7 (CH_2); 63.8 (CH_2), 58.2 (CH_2), 44.5 (t, *J* = 20.6 Hz, CH), 24.1 (CH_2), 15.8 (CH_3), 15.4 (CH_3), 15.0 (CH_3) ppm. MS (EI): *m*/*z* (%) = 591 (14), 533 (78), 505 (100), 389 (28), 441 (10), 135 (7), 103 (77), 91 (9), 75 (42). HRMS: *m*/*z* calcd. for $C_{17}H_{16}F_{17}O_3$ ([M – OEt]$^+$) 591.0839; found 591.0828.

Acetate Protection of 1a; Formation of (*E*)-4,5,5-Triethoxypent-3-enyl Acetate (3a): To a solution of **2a** (2.45 g, 11.24 mmol), triethylamine (2 mL, 14.46 mmol), and 4-DMAP (0.05 g, 0.41 mmol) at 0 °C under N_2 atmosphere was added acetic anhydride (2 mL, 21.18 mmol). After 40 min water was added and the mixture was extracted with DCM. The combined organic extracts were dried ($MgSO_4$) and filtered. Evaporation of the solvent gave 2.95 g of a yellowish liquid. The crude product was purified by flash chromatography (hexane/ethyl acetate in a 85:15 ratio) to give (2.51 g, 86%) of the title compound as a clear liquid. IR (film): $\tilde{\nu}_{max}$ = 2975 (s), 2898 (s), 2931 (s), 1740 (s), 1664 (m), 1446 (m), 1381 (m), 1239 (s), 1178 (s), 1118 (s), 1061 (s), 926 (m), 898 (m), 842 (w), 812 (m), 691 (w), 673 (w), 630 (m), 604 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 5.00 (s, 1 H, 5-H), 4.54 (t, $^3J_{H,H}$ = 7.8 Hz, 1-H, 3-H), 4.06 (t, $^3J_{H,H}$ = 6.9 Hz, 1-H), 3.76–3.46 (m, 6 H, 3 CH_2 of 3 OEt), 2.42 (m, 2 H, 2-H), 2.05 [s, 3 H, $CH_3C(O)$], 1.35–1.20 (m, 9 H, 3 CH_3 of 3 OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 170.9 (C), 153.4 (C), 99.1 (CH), 96.3 (CH), 64.6 (CH_2), 62.5 (CH_2), 62.3 (2 × CH_2), 24.8 (CH_2), 20.8 (CH_3), 15.0 (2 × CH_3), 14.2 (CH_3) ppm. MS (EI): *m/z* (%) = 214 (7), 200 (67), 171 (8), 155 (87), 143 (6), 127 (15), 103 (100), 85 (43), 75 (85), 69 (27), 57 (15), 43 (91). HRMS: *m/z* calcd. for $C_{11}H_{19}O_4$ ([M – OEt]$^+$) 215.1283; found 215.1282.

General Procedure for Perfluoroalkylation of Ester 3a: To a solution of **3a** (2.6 g, 10 mmol), CH_3CN (10.7 mL), H_2O (8.9 mL) and R_FI (11 mmol) at 0 °C under N_2 was added $NaHCO_3$ (0.93 g, 11 mmol) and sodium dithionite ($Na_2S_2O_4$) (1.90 g, 11 mmol). The solution was stirred overnight followed by addition of H_2O and extraction with DCM. The combined organic extracts were dried with $MgSO_4$ and filtered to remove the drying agent. Evaporation of the solvent gave a clear residue, which was purified by flash chromatography (hexane/ethyl acetate in a 85:15 ratio) to give the corresponding 5,5-diethoxy-4-oxo-3-(perfluoroalkyl)pentyl acetate (**4a**).

5,5-Diethoxy-4-oxo-3-(perfluorobutyl)pentyl Acetate (4a-I): The compound, 2.75 g (61% yield), was obtained as a clear liquid. IR (film): $\tilde{\nu}_{max}$ = 2980 (s), 2933 (s), 1747 (s), 1448 (m), 1369 (m), 1233 (s), 1134 (s), 1061 (s), 914 (m), 885 (m), 811 (w), 743 (w), 695 (w) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.61 (s, 1 H, 5-H), 4.26–3.92 (m, 3 H, 1-H and 3-H), 3.85–3.52 (m, 4 H, 2 CH_2 of 2 OEt), 2.34–2.11 (m, 2 H, 2-H), 2.04 [s, 3 H, $CH_3C(O)$], 1.25 (t, $^3J_{H,H}$ = 7.0 Hz, 6 H, 2 CH_3 of 2 OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 198.9 (C), 170.6 (C), 102.2 (CH), 64.4 (CH_2), 63.9 (CH_2), 61.1 (CH_2), 40.0 (t, *J* = 20.5 Hz, CH), 25.5 (CH_2), 20.7 (CH_3), 14.9 (CH_3), 14.8 (CH_3) ppm. MS (EI): *m/z* (%) = 449 (1), 405 (1), 362 (1), 235 (1), 318 (3), 289 (3), 241 (3), 195 (2), 103 (100), 75 (55), 61 (5), 47 (77). HRMS: *m/z* calcd. for $C_{15}H_{19}O_5F_9$ [M$^+$] 450.1089; found 450.1068.

5,5-Diethoxy-4-oxo-3-(perfluorohexyl)pentyl Acetate (4a-II): The compound, 4.16 g (76% yield), was obtained as a clear liquid. IR (film): $\tilde{\nu}_{max}$ = 2983 (s), 2939 (s), 2899 (s), 1748 (s), 1447 (m), 1366 (m), 1316 (m), 1231 (s), 1146 (s), 1063 (s), 939 (w), 910 (w), 859 (w), 806 (w), 736 (m), 705 (m), 635 (m), 599 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.62 (s, 1 H, 5-H), 4.27–3.93 (m, 3 H, 1-H and 3-H), 3.86–3.53 (m, 4 H, 2 CH_2 of 2 OEt), 2.35–2.13 (m, 2 H, 2-H), 2.04 [s, 3 H, $CH_3C(O)$], 1.25 (t, $^3J_{H,H}$ = 7.0 Hz, 6 H, 2 CH_3 of 2 OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 198.8 (C), 170.5 (C), 102.2 (CH), 64.3 (CH_2), 63.9 (CH_2), 61.1 (CH_2), 43.1 (t, *J* = 20.3 Hz, CH), 25.5 (CH_2), 20.5 (CH_3), 14.8 (CH_3), 14.6 (CH_3) ppm. MS (EI): *m/z* (%) = 505 (10), 517 (22), 491 (1), 462 (2), 389 (7), 103 (94), 75 (50), 61 (7). HRMS: *m/z* calcd. for $C_{15}H_{14}O_4F_{13}$ (M – OEt)$^+$ 505.0685; found 505.0666.

Reduction of 4a-I; Formation of 5,5-Diethoxy-3-(perfluorobutyl)-pentane-1,4-diol (6a-I) and 2-(Diethoxymethyl)-3-(perfluorobutyl)-tetrahydrofuran-2-ol (7a-I): The procedure is based on a protocol published by Corey and co-workers.[10] To a stirred solution of (*S*)-oxazaborolidine (0.3 mmol) in $BH_3 \cdot Me_2S$ in dry THF (3.0 mL of a 2.0 M solution, 6.0 mmol) and dry THF (5 mL) kept at room temperature was added **4a-I** (2.47 g, 5.49 mmol) in dry THF (5 mL) during 5 min. Additional $BH_3 \cdot Me_2S$ in dry THF (1.0 mL of a 2.0 M solution, 2.0 mmol) was added after 4 h. After stirring for another 5 h the reaction was quenched by adding MeOH and the mixture was extracted with DCM. The combined organic extracts were dried ($MgSO_4$) and filtered. Evaporation of the solvent gave 2.32 g of a slightly yellow liquid. The crude product was purified by flash chromatography (hexane/ethyl acetate gradient changing gradually from a 70:30 to a 50:50 ratio) to give 0.45 g (20%) of **6a-I** and 1.14 g (51%) of **7a-I**.

6a-I: IR (film): $\tilde{\nu}_{max}$ = 3420 (br. s), 2980 (s), 2935 (s), 2898 (s), 1449 (m), 1380 (m), 1349 (m), 1234 (s), 1131 (s), 1061 (s), 960 (m), 888 (m), 825 (m), 740 (m), 687 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.66 and 4.65 (2d in a 1.0:1.0 ratio, $^3J_{H,H}$ = 6.7 Hz, 1 H, 5-H), 3.92–3.49 (m, 8 H, 2 CH_2 of 2 OEt, 2 OH and 1-H), 3.26 (br. s, 1 H, 4-H), 2.87 (m, 1 H, 3-H), 2.08–1.98 (m, 2 H, 2-H), 1.25 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt), 1.21 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 103.6 and 103.4 (CH), 71.8 and 71.7 (CH), 64.3 (CH_2), 64.1 (CH_2), 59.4 (CH_2), 39.1 (t, *J* = 19.0 Hz, CH), 28.1 (CH_2), 15.2 (CH_3), 14.9 (CH_3) ppm. MS (EI): *m/z* (%) = 365 (12), 347 (58), 319 (32), 241 (6), 103 (100), 93 (7), 75 (67), 60 (10), 47 (100). HRMS: *m/z* calcd. for $C_{11}H_{13}O_3F_9$ ([M – OEt]$^+$) 364.0799; found 364.0793.

7a-I: IR (film): $\tilde{\nu}_{max}$ = 3471 (m, br), 2979 (s), 2933 (s), 2903 (s), 1455 (m), 1350 (s), 1220 (s), 1134 (s), 1073 (s), 982 (s), 937 (m), 897 (m), 797 (m), 740 (m), 719 (m), 688 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.68 and 4.67 [2s in a 1.0:1.0 ratio, 1 H, $CH(OEt)_2$], 4.26–4.15 (m, 1 H, 5-H), 4.05–3.82 (m, 3 H, CH_2 of OEt and 5-H), 3.76–3.58 (m, 2 H, CH_2 of OEt), 3.43 (s, 1 H, OH), 3.26–3.03 (m, 1 H, 3-H), 2.46–2.18 (m, 2 H, 4-H), 1.32–1.22 (m, 6 H, 2 CH_3 of 2 OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 104.4 (C), 103.1 and 103.0 (CH), 66.3 (CH_2), 65.7 (CH_2), 65.3 (CH_2), 42.8 (t, *J* = 20.4 Hz, CH), 24.6 (CH_2), 15.1 (CH_3), 14.9 (CH_3) ppm. MS (EI): *m/z* (%) = 391 (2), 361 (2), 247 (1), 333 (2), 317 (22), 305 (28), 289 (10), 241 (16), 195 (7), 103 (100), 91 (10), 75 (74), 47 (74). HRMS: *m/z* calcd. for $C_{13}H_{16}O_3F_9$ ([M – OH]$^+$) 391.0956; found 391.0963.

Reduction of 4a-II; Formation of 5,5-Diethoxy-4-hydroxy-3-(perfluorohexyl)pentyl Acetate (5a-II): To a solution of $NaBH_4$ (0.020 g, 0.53 mmol) in EtOH (5 mL) was added **4a-II** (0.28 g, 0.51 mmol) in 75% aqueous EtOH (5 mL) during 5 min at 0 °C. After 40 min H_2O was added and the mixture was extracted with DCM. The combined organic extracts were dried ($MgSO_4$) and filtered. Evaporation of the solvent gave 0.19 g (68%) of **5a-II** as a clear liquid. IR (film): $\tilde{\nu}_{max}$ = 3491 (m), 2980 (s), 2932 (s), 1742 (s), 1450 (m), 1367 (s), 1233 (s), 1142 (s), 1060 (s), 966 (w), 907 (w), 882 (w), 837 (w), 806 (m), 773 (w), 737 (m), 707 (m), 661 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.67 and 4.66 (2d in a 1.0:1.0 ratio, $^3J_{H,H}$ = 6.9 Hz, 1 H, 5-H), 4.31–4.05 (m, 2 H, 1-H), 3.92–3.48 (m, 5 H, 2 CH_2 of 2 OEt and 4-H), 2.89–2.76 (m, 1 H, 3-H), 2.53–2.51 (m, 1 H, OH), 2.17–2.03 (m, 2 H, 2-H), 2.05 [s, 3 H, $CH_3C(O)$], 1.26 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt), 1.21 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 170.8 (C), 103.3 and 103.1 (CH), 71.9 (CH), 64.3 (CH_2), 64.2 (CH_2), 61.6 (CH_2), 38.2 (t, *J* = 19.3 Hz, CH), 24.7 (CH_2), 20.7 (CH_3), 15.4 (CH_3), 15.1 (CH_3) ppm. MS (EI): *m/z* (%) = 507 (1), 461 (1), 447 (11), 419 (10), 103 (100), 87 (7), 75 (55), 59 (16), 47 (77). HRMS: *m/z* calcd. for $C_{15}H_{16}O_4F_{13}$ ([M – OEt]$^+$) 507.0841; found 507.0823.

Deprotection of 5a-II; Formation of 5,5-Diethoxy-3-(perfluorohexyl)-pentane-1,4-diol (6a-II): To a solution of **5a-II** (0.36 g, 0.65 mmol) in moist MeOH (12.5 mL) was added NaOMe (0.1 g, 1.85 mmol) at room temperature. After 30 min the reaction was quenched by the addition of aqueous NH_4Cl and the mixture was extracted with

DCM. The combined organic extracts were dried ($MgSO_4$) and filtered. Evaporation of the solvent gave 0.30 g (89%) of **6a-II** as a clear liquid. IR (film): $\tilde{\nu}_{max}$ = 3418 (s), 2979 (s), 2937 (s), 2901 (s), 1449 (m), 1355 (m), 1203 (s), 1141 (s), 1061 (s), 907 (m), 882 (m), 804 (m), 738 (m), 705 (m), 660 (m) cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.67 and 4.66 (2d in a 1.0:1.0 ratio, $^3J_{H,H}$ = 6.6 Hz, 1 H, 5-H), 3.92 (d, $^3J_{H,H}$ = 6.0 Hz, 2 H, 1-H), 3.87–3.53 (m, 7 H, 2 CH_2 of 2 OEt, 2 OH and 4-H), 2.87 (m, 1 H, 3-H), 2.13–1.92 (m, 2 H, 2-H), 1.26 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt), 1.21 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 103.5 and 103.4 (CH), 72.9 (CH), 64.1 (CH_2), 64.0 (CH_2), 60.1 (CH_2), 39.6 (t, *J* = 19.0 Hz, CH), 28.2 (CH_2), 15.2 (CH_3), 14.8 (CH_3) ppm. MS (EI): *m*/*z* (%) = 509 (1), 464 (10), 447 (65), 420 (78), 403 (58), 389 (70), 341 (78), 294 (52), 168 (18), 145 (19), 131 (32), 119 (53), 104 (94), 87 (90), 69 (91), 60 (100). HRMS: *m*/*z* calcd. for $C_{13}H_{14}O_3F_{13}$ ([M – OEt]$^+$) 465.0735; found 465.0739.

Cyclization of 6a-II; Formation of 2-Ethoxy-4-(perfluorohexyl)tetrahydro-3*H*-pyran-3-ol (8a-II) and 5,5-Diethoxy-4-hydroxy-3-(perfluorohexyl)pentyl Formate (9): To a solution of diol **6a-II** (0.11 g, 0.22 mmol) in pentane (5 mL) was added 80% aqueous HCOOH (10 drops) at room temperature. After stirring for 23 h H_2O was added and the mixture extracted with DCM. The combined organic extracts were dried with $MgSO_4$ and filtered. Evaporation of the solvent gave 0.11 g of a yellow liquid, from which tetrahydrofuranol **8a-II** (0.040 g, 40%) was isolated as a clear liquid and ester **9** (0.060 g, 52%) as a yellowish liquid by flash chromatography (hexane/ethyl acetate in a 80:20 ratio).

8a-II: IR (film): $\tilde{\nu}_{max}$ = 3475 (m), 2978 (m), 2933 (m), 1450 (m), 1357 (m), 1237 (s), 1202 (s), 1145 (s), 1087 (m), 1006 (m), 942 (w), 896 (w), 843 (w), 810 (w), 734 (m), 702 (m), 655 (m) cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.21 (d, $^3J_{H,H}$ = 7.3 Hz, 1 H, 5-H), 4.03 (dd, $^3J_{H,H}$ = 4.6, $^2J_{H,H}$ = 12.0 Hz, 1 H, 6-H), 4.00–3.92 (m, 1 H, 1 H of CH_2 of OEt), 3.87–3.71 (m, 1 H, 3-H), 3.67–3.60 (m, 1 H, 1 H of CH_2 of OEt), 3.49 (dt, $^3J_{H,H}$ = 3.0, $^2J_{H,H}$ = 12.0 Hz, 1 H, 6-H), 2.62–2.49 (m, 1 H, 4-H), 2.18 (br. s, 1 H, OH), 1.90–1.72 (m, 2 H, 5-H), 1.27 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 104.1 (CH), 67.9 (CH), 66.3 (CH_2), 63.3 (CH_2), 43.9 (t, *J* = 20.5 Hz, CH), 24.2 (CH_2), 15.2 (CH_3) ppm. MS (EI): *m*/*z* (%) = 463 (3), 435 (4), 419 (60), 389 (8), 341 (35), 295 (22), 245 (3), 169 (8), 119 (38), 93 (100), 75 (78), 71 (58), 59 (49). HRMS: *m*/*z* calcd. for $C_{13}H_{13}O_3F_{13}$ [M$^+$] 464.0657; found 464.0649.

9: IR (film): $\tilde{\nu}_{max}$ = 3463 (m), 2974 (s), 2931 (s), 1728 (s), 1451 (m), 1356 (m), 1241 (s), 1141 (s), 890 (m), 806 (m), 736 (m), 704 (m) cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 8.06 [s, 1 H, HC(O)], 4.66–4.65 (2d in a 1.0:1.0 ratio, $^3J_{H,H}$ = 6.8 Hz, 1 H, 5-H), 4.38–4.32 (m, 1 H, 1-H), 4.27–4.21 (m, 1 H, 1-H), 3.89–3.50 (m, 6 H, 2 CH_2 of 2 OEt, 4-H and OH), 2.86–2.80 (m, 1 H, 3-H), 2.24–2.06 (m, 2 H, 2-H), 1.26 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt), 1.21 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 160.6 (CH), 103.2 and 103.1 (CH), 71.8 (CH), 64.3 (CH_2), 64.2 (CH_2), 61.3 (CH_2), 38.6 (t, *J* = 20.0 Hz, CH), 24.7 (CH_2), 15.5 (CH_3), 15.1 (CH_3) ppm. MS (EI): *m*/*z* (%) = 503 (2), 493 (1), 463 (1), 447 (90), 419 (95), 403 (28), 389 (31), 341 (48), 295 (22), 245 (3), 169 (4), 119 (28), 104 (73), 87 (79), 75 (100), 60 (80). HRMS: *m*/*z* calcd. for $C_{11}H_8O_2F_{13}$ ([M – CHO – 2 OEt]$^+$) 419.0317; found 419.0339.

Sulfuric Acid-Catalyzed Ring Closure of 1a; Formation of (Diethoxymethyl)-2-ethoxy-2-tetrahydrofuran (10a): To a stirred solution of **1a** (0.12 g, 0.55 mmol) in dry EtOH (5 mL) kept at room temperature was added concd. H_2SO_4 (3 drops). After 2 h of stirring the reaction was quenched by adding aq. $NaHCO_3$ followed by extraction with DCM. The combined organic extracts were dried with $MgSO_4$, filtered, and the solvent evaporated to give essentially pure **10a** (0.10 g, 83%). IR (film): $\tilde{\nu}_{max}$ = 3251 (m), 2966 (s), 2739 (m), 1738 (m), 1675 (m), 1446 (s), 1385 (m), 1341 (m), 1268 (m), 1199 (s), 1065 (s), 980 (s), 927 (m), 875 (m) 806 (m), 732 (w), 697 (w), 645 (m) cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.60 [s, 1 H, $CH(OEt)_2$], 3.89–3.38 (m, 8 H, 3 CH_2 of 3 OEt and 5-H), 1.94–1.66 (m, 4 H, 3-H and 4-H), 1.29–1.15 (m, 9 H, 3 CH_3 of 3 OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 103.7 (C), 97.4 (CH), 62.5 (CH_2), 58.9 (CH_2), 55.2 (CH_2), 55.1 (CH_2), 26.3 (CH_2), 22.8 (CH_2), 15.4 (CH_3), 15.3 (CH_3), 14.9 (CH_3) ppm. MS (EI): *m*/*z* (%) = 217 (1), 189 (96), 173 (94), 144 (83), 127 (75), 117 (83), 103 (73), 99 (100), 89 (87), 72 (98). HRMS: *m*/*z* calcd. for $C_9H_{17}O_3$ ([M – OEt]$^+$) 173.1178; found 173.1174.

Formic Acid Catalyzed Ring Closure of 1a; Formation of 2,3-Diethoxy-5,6-dihydro-2*H*-pyran (11a): To a stirred solution of **1a** (0.11 g, 0.50 mmol) in pentane (5 mL) was added 80% aq. HCOOH (10 drops) at room temp. After stirring the reaction mixture for 30 min at this temperature H_2O was added and the mixture extracted with DCM. The combined extracts were dried with $MgSO_4$, filtered and the solvent was evaporated to give a greenish crude product, from which **11a** (0.049 g, 57%) was isolated by flash chromatography (hexane/ethyl acetate in a 92.5:7.5 ratio). IR (film): $\tilde{\nu}_{max}$ = 3064 (w), 2974 (s), 2898 (s), 2743 (w), 1721 (w), 1673 (s), 1443 (m), 1384 (s), 1337 (m), 1310 (m), 1228 (s), 1194 (s), 1066 (s), 945 (m), 891 (w), 836 (m), 790 (m), 701 (w), 657 (w) cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.80 (dd, $^3J_{H,H}$ = 2.2, $^3J_{H,H}$ = 5.8 Hz, 1 H, 4-H), 4.76 (s, 1 H, 2-H), 3.99–3.50 (m, 6 H, 2 CH_2 of 2 OEt and 6-H), 2.47–2.29 (m, 1 H, 5-H), 2.00–1.87 (m, 1 H, 5-H), 1.30 [t, $^3J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt], 1.26 (t, $^3J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 151.3 (C), 94.2 (CH), 93.7 (CH), 63.1 (CH_2), 61.9 (CH_2), 57.1 (CH_2), 23.2 (CH_2), 15.0 (CH_3), 14.1 (CH_3) ppm. MS (EI): *m*/*z* (%) = 172 (32), 143 (18), 127 (100), 115 (15), 99 (54), 81 (20), 69 (83), 53 (27). HRMS: *m*/*z* calcd. for $C_7H_{11}O_2$ [M$^+$] 127.0759; found 127.0763.

1-Iodoperfluoroalkylation of 11a; General Procedure: To a stirred solution of **11a** (0.172 g, 1.0 mmol), CH_3CN (1.1 mL), H_2O (0.9 mL) and perfluoroalkyl iodide (1.10 mmol) kept at 0 °C under N_2 atmosphere were added $NaHCO_3$ (0.090 g, 1.07 mmol) and sodium dithionite ($Na_2S_2O_4$) (0.19 g, 1.09 mmol). The solution instantly turned milky white. After stirring for 15–19 h H_2O was added and the mixture extracted with DCM. The combined organic extracts were dried ($MgSO_4$) and then filtered before the solvent was evaporated. An essentially pure sample of the corresponding 2-ethoxy-4-(perfluoroalkyl)tetrahydropyran-3-one (**12a**) was left behind.

2-Ethoxy-4-(perfluorobutyl)tetrahydropyran-3-one (12a-I): The compound was obtained as a slightly yellow liquid (0.32 g, 89%). IR (film): $\tilde{\nu}_{max}$ = 2982 (s), 2937 (s), 2900 (s), 1755 (s), 1674 (w), 1451 (m), 1379 (m), 1349 (s), 1306 (s), 1210 (s), 1132 (s), 1058 (s), 946 (s), 888 (s), 812 (m), 736 (m), 696 (m), 654 (m), 561 (s) cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.78 and 4.71 (2s in a 44:56 ratio, 1 H, 2-H), 4.30–4.14 (m, 1 H, 1 H of CH_2 of OEt), 4.00–3.74 (m, 3 H, 1 H of CH_2 of OEt and 6-H), 3.70–3.50 (m, 1 H, 4-H), 2.46–2.23 (m, 2 H, 5-H), 1.28 and 1.27 (2 partly overlapping t, $^3J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 194.9 and 194.1 (C), 99.8 and 98.8 (CH), 64.5 and 64.0 (CH_2), 58.4 and 57.9 (CH_2), 46.6 (CH, both isomers), 28.9 and 23.8 (CH_2), 14.7 and 14.6 (CH_3) ppm. MS (EI): *m*/*z* (%) = 362 (2), 334 (18), 317 (10), 289 (10), 241 (8), 121 (6), 91 (67), 75 (35), 47

(100). HRMS: m/z calcd. for $C_{11}H_{11}O_3F_9$ [M$^+$] 362.056449; found 362.054550.

2-Ethoxy-4-(perfluorohexyl)tetrahydropyran-3-one (12a-II): The compound was obtained as a clear liquid (0.32 g, 70%). IR (film): $\tilde{\nu}_{max}$ = 2982 (s), 2937 (s), 2899 (s), 1752 (s), 1674 (w), 1623 (w), 1449 (m), 1362 (s), 1312 (s), 1204 (s), 1146 (s), 1119 (s), 1059 (s), 885 (m), 852 (m), 805 (m), 735 (m), 703 (m), 641 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.78 and 4.71 (2s in a 52:48 ratio, 1 H, 2-H), 4.26–4.17 (m, 1 H, 1 H of CH_2 of OEt), 3.90–3.77 (m, 3 H, 1 H of CH_2 of OEt and 6-H), 3.68–3.47 (m, 1 H, 4-H), 2.46–2.26 (m, 2 H, 5-H), 1.28 and 1.27 (2 partly overlapping t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 195.0 and 194.2 (C), 99.7 and 98.8 (CH), 64.5 and 64.0 (CH_2), 58.4 and 57.9 (CH_2), 46.7 (CH, both isomers), 28.9 and 23.9 (CH_2), 14.9 and 14.8 (CH_3) ppm. MS (EI): m/z (%) = 462 (3) [M$^+$], 417 (4), 397 (50), 369 (91), 349 (44), 321 (38), 321 (24), 295 (23), 171 (100), 153 (73), 121 (71), 101 (89), 69 (88). HRMS: m/z calcd. for $C_{13}H_{11}O_3F_{13}$ [M$^+$] 462.0501; found 462.0512.

2-Ethoxy-4-(perfluorooctyl)tetrahydropyran-3-one (12a-III): The compound was obtained as a slightly yellow liquid (0.38 g, 68%). IR (film): $\tilde{\nu}_{max}$ = 2982 (s), 2938 (s), 2898 (s), 1756 (s), 1675 (m), 1450 (m), 1368 (s), 1207 (s), 887 (m), 808 (m), 781 (m), 726 (s), 711 (s), 656 (s) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.78 and 4.71 (2s in a 38:62 ratio, 1 H, 2-H), 4.30–4.17 (m, 1 H, 1 H of CH_2 of OEt), 3.94–3.76 (m, 3 H, 1 H of CH_2 of OEt and 6-H), 3.66–3.56 (m, 1 H, 4-H), 2.42–2.30 (m, 2 H, 5-H), 1.28 and 1.27 (2 partly overlapping t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 195.0 (minor) and 194.1 (major) (C), 99.9 (major) and 98.8 (minor) (CH), 64.5 (minor) and 64.0 (major) (CH_2), 58.4 (minor) and 57.9 (major) (CH_2), 46.5 (CH, both isomers), 28.9 (major) and 23.9 (minor) (CH_2), 14.8 (major) and 14.7 (minor) (CH_3) ppm. MS (EI): m/z (%) = 534 (11), 517 (14), 489 (7), 469 (5), 441 (4), 121 (11), 103 (7), 91 (72), 75 (26), 46 (100).

Decomposition of 12a on a Silica-Gel Column; General Procedure: 4-(Perfluoroalkyl)tetrahydropyran-3-ones **12a-I**, **12a-II**, and **12a-III** were eluted on a flash-chromatography column using Merck 60 Kieselgel (230–400 mesh) as stationary phase and a gradient going from hexane/ethyl acetate mixture (95:5 to 90:10) as the mobile phase. The fractions collected contained either no product(s) or one product (mixture) which gave a single spot when analyzed by TLC. The product-containing fractions were combined, the solvents were evaporated, and the residue was thoroughly analyzed chromatographically and spectroscopically and by mass spectrometry. The residues turned out to be essentially pure *Z*/*E* mixtures of the corresponding 2-ethoxy-4-(perfluoroalkylidene)tetrahydropyan-3-ones **13a**.

(*Z*/*E*)-2-Ethoxy-4-(perfluorobutylidene)tetrahydropyran-3-one (13a-I): Elution of **12a-I** (0.32 g) gave 0.21 g (62%) of the title compound. IR (film): $\tilde{\nu}_{max}$ = 2983 (s), 2935 (s), 2900 (s), 1739 (s), 1673 (m), 1445 (m), 1354 (s), 1307 (s), 1218 (s), 1124 (s), 1053 (s), 995 (s), 930 (s), 913 (s), 860 (m), 807 (m), 746 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.82 and 4.81 (2s in a 1:4 ratio, 1 H, 2-H), 4.22–4.10 (m, 1 H, 6-H), 3.88–3.76 (m, 2 H, 1 H of CH_2 of OEt and 1 H, 6-H), 3.70–3.58 (m, 1 H, 1 H of CH_2 of OEt), 2.92–2.80 (m, 2 H, 5-H), 1.27 and 1.26 (2 partly overlapping t, $^{3}J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 188.9 (C), 122.3 (C), 99.9 (minor) and 99.4 (major) (CH), 64.3 (major) and 64.1 (minor) (CH_2), 58.1 (minor) and 58.0 (major) (CH_2), 30.3 (minor) and 27.4 (major) (CH_2), 14.8 (minor) and 14.7 (major) (CH_3) ppm. MS (EI): m/z (%) = 289 (25), 269 (72), 240 (24), 221 (10), 195 (13), 171 (26), 149 (15), 121 (78), 103 (55), 93 (52), 75 (57). HRMS: m/z calcd. for $C_9H_5O_2F_8$, ([M – OEt]$^+$) 297.0162; found 297.0143.

(*Z*/*E*)-2-Ethoxy-4-(perfluorohexylidene)tetrahydropyran-3-one (13a-II): Elution of **12a-II** (0.32 g) gave 0.27 g (62%) of the title compound. IR (film): $\tilde{\nu}_{max}$ = 2983 (s), 2936 (s), 2901 (s), 1739 (s), 1673 (m), 1444 (m), 1358 (s), 1313 (s), 1172 (s), 1055 (s), 1019 (s), 949 (s), 895 (m), 874 (m), 848 (m), 813 (m), 728 (s), 663 (m), 632 (m), 537 (s), 449 (s) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.82 and 4.81 (2s in a 1:4 ratio, 1 H, 2-H), 4.23–4.10 (m, 1 H, 6-H), 3.88–3.76 (m, 2 H, 1 H of CH_2 of OEt and 6-H), 3.66–3.55 (m, 1 H, 1 H of CH_2 of OEt), 2.92–2.81 (m, 2 H, 5-H), 1.27 and 1.26 (2 partly overlapping t, $^{3}J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 188.9 (C), 122.4 (C), 100.0 (minor) and 99.3 (major) (CH), 64.3 (major) and 64.1 (minor) (CH_2), 58.1 (minor) and 57.9 (major) (CH_2), 30.3 (minor) and 27.4 (major) (CH_2), 14.7 (minor), 14.6 (major) (CH_3) ppm. MS (EI): m/z (%) = 414 (6), 297 (90), 369 (100), 349 (8), 171 (25), 153 (10), 121 (30), 101 (15), 69 (7). HRMS: m/z calcd. for $C_{13}H_{10}O_3F_{12}$ [M$^+$] 442.0438; found 442.0442.

(*Z*/*E*)-2-Ethoxy-4-(perfluorooctylidene)tetrahydropyran-3-one (13a-III): Elution of **12a-III** (0.44 g) gave 0.18 g (34%) of the title compound. IR (film): $\tilde{\nu}_{max}$ = 2983 (m), 2935 (m), 2902 (m), 1740 (m), 1673 (w), 1445 (w), 1364 (m), 1317 (m), 1207 (s), 1148 (s), 1052 (s), 983 (m), 897 (m), 865 (w), 805 (w), 780 (w), 713 (m), 661 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.82 and 4.81 (2s in a 1:4 ratio, 1 H, 2-H), 4.23–4.10 (m, 1 H, 6-H), 3.89–3.77 (m, 2 H, 1 H of CH_2 of OEt and 1 H, 6-H), 3.70–3.55 (m, 1 H, 1 H of CH_2 of OEt), 3.07–2.79 (m, 2 H, 5-H), 1.26 (major isomer) and 1.25 (minor isomer) (t, $^{3}J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 188.9 (C), 122.4 (C), 100.0 (minor) and 99.4 (major) (CH), 64.2 (major) and 64.1 (minor) (CH_2), 58.1 (minor) and 58.0 (minor) (CH_2), 30.3 (minor) and 27.5 (major) (CH_2), 14.7 (major) and 14.6 (major) (CH_3) ppm. MS (EI): m/z (%) = 514 (6), 497 (65), 469 (100), 449 (15), 171 (47), 153 (18), 133 (12), 121 (73), 101 (34), 69 (39).

Reduction of 2-Ethoxy-4-(perfluorobutyl)tetrahydropyran-3-one [(2*R,4*R**/4*S**)-12a-I]; Formation of (2*R**,3*R**/3*S**,4*R**/4*S**)-8a-I:** To a stirred solution of $NaBH_4$ (0.020 g, 0.53 mmol) in 75% EtOH/H_2O (5 mL) kept at room temperature was added dropwise a solution of **12a-I** (0.18 g, 0.50 mmol) in 75% EtOH/H_2O (5 mL) during 5 min. After stirring for 4 h H_2O was added and the hydrolysate was extracted with DCM. The combined organic extracts were dried ($MgSO_4$) and filtered. Evaporation of the solvent gave 0.18 g (94%) of (2*R**,3*R**/3*S**,4*R**/4*S**)-**8a-I** as a yellowish liquid. Its isomeric composition was determined by ^{1}H NMR investigations of the product mixture before isolation of the major isomers started, using the integrals of the anomeric protons to determine the isomeric composition. The anomeric protons showed the following chemical shifts and relative intensities: 4.70 ppm, 22% (3*R**,4*R**); 4.43 ppm, 11% (3*R**,4*S**); 4.83 ppm, 34% (3*S**,4*R**); 4.35 ppm, 33% (3*S**,4*S**). Separation and purification were carried out by flash chromatography (hexane/ethyl acetate in a 80:20 ratio), and the two most abundant isomers were isolated pure.

(2*R,3*S**,4*S**)-8a-I:** IR (film): $\tilde{\nu}_{max}$ = 3447 (br. s), 2983 (s), 2936 (s), 2885 (s), 1451 (m), 1381 (m), 1354 (m), 1296 (m), 1218 (s), 1132 (s), 1081 (s), 1010 (m), 965 (m), 896 (m), 815 (m), 729 (m), 695 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.35 (br. s, 1 H, 2-H), 4.12 (dd, $^{3}J_{H,H}$ = 4.7, $^{2}J_{H,H}$ = 12.1 Hz, 1 H, 6-H), 4.09 (s, 1 H, 3-H), 4.00–3.92 (m, $^{3}J_{H,H}$ = 7.0, $^{2}J_{H,H}$ = 9.5 Hz, 1 H, 1 H of CH_2 of OEt), 3.67–3.57 (m, $^{3}J_{H,H}$ = 7.0, $^{2}J_{H,H}$ = 9.5 Hz, 1 H, 1 H of CH_2 of OEt), 3.52 (dt, $^{3}J_{H,H}$ = 2.3, $^{2}J_{H,H}$ = 12.1 Hz, 1 H, 6-H), 2.45–2.34 (m, 1 H, 4-H), 2.30 (br. s, 1 H, OH), 2.19 (dq, $^{3}J_{H,H}$ =

4.7, $^{2}J_{H,H}$ = 13.1 Hz, 1 H, 5-H), 1.62 (br. d, $^{2}J_{H,H}$ = 13.1 Hz, 1 H, 5-H), 1.25 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 100.3 (CH), 64.9 (CH), 64.5 (CH_2), 53.9 (CH_2), 41.8 (t, J = 21.3 Hz, CH), 19.1 (CH_2), 15.0 (CH_3) ppm. MS (EI): m/z (%) = 363 (3), 336 (8), 319 (53), 301 (7), 289 (10), 241 (48), 195 (38), 177 (8), 145 (12), 121 (20), 102 (22), 93 (92), 75 (100). HRMS: m/z calcd. for $C_9H_8O_2F_9$ ($[M - OEt]^+$) 319.0381; found 319.0376.

(2*R,3*S**,4*R**)-8a-I:** IR (film): $\tilde{\nu}_{max}$ = 3475 (m), 2978 (s), 2938 (s), 2896 (s), 1450 (m), 1382 (m), 1349 (s), 1309 (s), 1225 (s), 1134 (s), 1078 (s), 1009 (s), 944 (m), 904 (m), 876 (m), 788 (m), 732 (m), 694 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.83 (d, $^{3}J_{H,H}$ = 3.7 Hz, 1 H, 2-H), 3.87–3.79 (m, 2 H, 1 H of CH_2 of OEt and 3-H), 3.74 (dt, $^{3}J_{H,H}$ = 2.5, $^{2}J_{H,H}$ = 12.0 Hz, 1 H, 6-H), 3.64–3.51 (m, 2 H, 1 H of CH_2 of OEt and 4-H), 2.78–2.65 (m, $^{3}J_{H,H}$ = 4.0, $^{2}J_{H,H}$ = 12.0 Hz, 1 H, 6-H), 2.03 (br. s, 1 H, OH), 1.86 (br. d, $^{2}J_{H,H}$ = 13.1 Hz, 1 H, 5-H), 1.74 (dq, $^{3}J_{H,H}$ = 5.0, $^{2}J_{H,H}$ = 13.1 Hz, 1 H, 5-H), 1.27 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$, Me_4Si): δ = 97.5 (CH), 66.5 (CH), 63.6 (CH_2), 57.6 (CH_2), 41.5 (t, J = 20.5 Hz, CH), 23.9 (CH_2), 15.0 (CH_3) ppm. MS (EI): m/z (%) = 364 (3), 336 (34), 319 (65), 301 (38), 289 (37), 241 (60), 195 (83), 177 (41), 145 (38), 119 (65), 102 (71), 91 (79), 71 (100). HRMS: m/z calcd. for $C_9H_8O_2F_9$ ($[M - OEt]^+$) 319.0381; found 319.0399.

Investigations Based on 1b–1f

Ring Closure of 1b–1f Catalyzed by Formic Acid: The reactions were performed following the procedure used to synthesize 2,3-diethoxy-5,6-dihydro-2*H*-pyran (**11a**) from **1a** (vide supra). The following products were obtained.

2,3-Diethoxy-6-methyl-5,6-dihydro-2*H*-pyran [(2*R,6*R**/6*S**)-11b]:** The compound, 0.048 g (52% yield), was obtained as a yellowish liquid over two steps from 5,5,6,6-tetraethoxy-3-hexyn-2-ol.[8] Pure samples of the *cis* (2*R**,6*R**)-**11b** and *trans* (2*R**,6*S**)-**11b** isomers were isolated by flash chromatography (hexane/ethyl acetate in a 92.5:7.5 ratio). From the ^{1}H NMR spectrum of the crude product mixture the *cis*/*trans* ratio was determined to be 27:73.

(2*R,6*R**)-11b:** IR (film): $\tilde{\nu}_{max}$ = 3063 (w), 2974 (s), 2894 (s), 1670 (s), 1445 (m), 1379 (s), 1328 (m), 1294 (m), 1203 (s), 1156 (s), 1070 (s), 938 (m), 917 (m), 791 (m), 729 (w) cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si): δ = 5.10 (t, $^{5}J_{H,H}$ = 1.9 Hz, 1 H, 2-H), 4.81 (t, $^{3}J_{H,H}$ = 4.2 Hz, 1 H, 4-H), 3.86 (q, $^{3}J_{H,H}$ = 6.3 Hz, 1 H, 6-H), 3.81–3.61 (m, 4 H, 2 CH_2 of 2 OEt), 2.10–2.07 (m, 2 H, 5-H), 1.31 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt), 1.28 (d, $^{3}J_{H,H}$ = 6.3 Hz, 3 H, 6-Me), 1.25 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 150.9 (C), 95.9 (CH), 94.7 (CH), 68.4 (CH), 62.3 (CH_2), 62.0 (CH_2), 30.6 (CH_2), 20.8 (CH_3), 15.0 (CH_3), 14.2 (CH_3) ppm. MS (EI): m/z (%) = 186 (67), 157 (38), 141 (100), 129 (65), 113 (80), 95 (97), 86 (98), 67 (88), 57 (73). HRMS: m/z calcd. for $C_{10}H_{18}O_3$ $[M^+]$ 186.1256; found 186.1258.

(2*R,6*S**)-11b:** IR (film): $\tilde{\nu}_{max}$ = 3060 (w), 2974 (s), 2900 (s), 2841 (m), 1674 (m), 1445 (m), 1381 (s), 1337 (m), 1299 (m), 1199 (s), 1106 (s), 1062 (s), 966 (m), 909 (m), 874 (w), 795 (m), 736 (w), 663 (w) cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si): δ = 4.81 (s, 1 H, 2-H), 4.74 (t, $^{3}J_{H,H}$ = 4.0 Hz, 1 H, 4-H), 4.14–4.06 (m, 1 H, 6-H), 3.87–3.57 (m, 4 H, 2 CH_2 of 2 OEt), 2.04–2.01 (m, 2 H, 5-H), 1.30 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt), 1.26 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt), 1.23 (d, $^{3}J_{H,H}$ = 6.3 Hz, 3 H, 6-Me) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 151.3 (C), 95.2 (CH), 93.9 (CH), 63.2 (CH_2), 62.9 (CH), 62.2 (CH_2), 30.9 (CH_2), 20.5 (CH_3), 15.2 (CH_3), 14.2 (CH_3) ppm. MS (EI): m/z (%) = 186 (85), 157 (38), 141 (81), 129 (68), 113 (96), 95 (100), 86 (93), 67 (93), 57 (94). HRMS: m/z calcd. for $C_8H_{13}O_2$ ($[M - OEt]^+$) 141.0916; found 141.0910.

2,3-Diethoxy-6-hexyl-5,6-dihydro-2*H*-pyran [(2*R,6*R**/6*S**)-11c]:** The compound, 0.063 g (49% yield), was obtained as a colourless liquid over two steps from 1,1,2,2-tetraethoxy-3-undecyn-5-ol.[8] Pure samples of the *cis* (2*R**,6*R**)-**11c** and *trans* (2*R**,6*S**)-**11c** isomers were isolated by flash chromatography (hexane/ethyl acetate in a 92.5:7.5 ratio). From the ^{1}H NMR spectrum of the crude product mixture the *cis*/*trans* ratio was determined to be 38:62.

(2*R,6*R**)-11c:** IR (film): $\tilde{\nu}_{max}$ = 2975 (s), 2957 (s), 2859 (s), 1682 (m), 1517 (w), 1458 (m), 1443 (m), 1378 (m), 1327 (w), 1298 (w), 1259 (w), 1206 (s), 1152 (m), 1118 (s), 1072 (s), 939 (w), 788 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 5.08 (br. s, 1 H, 2-H), 4.80 (dd, $^{3}J_{H,H}$ = 2.8, $^{3}J_{H,H}$ = 5.6 Hz, 1 H, 4-H), 3.82–3.60 (m, 5 H, 2 CH_2 of 2 OEt and 6-H), 2.14–2.00 (m, 2 H, 5-H), 1.71–1.62 (m, 2 H, hexyl), 1.52–1.40 (m, 2 H, hexyl), 1.32–1.26 (m, 9 H, CH_3 of OEt and 3 CH_2 of hexyl), 1.24 (t, $^{3}J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt), 0.88 (m, 3 H, CH_3 of hexyl) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 151.3 (C), 96.3 (CH), 95.0 (CH), 72.6 (CH), 62.4 (CH_2), 62.3 (CH_2), 35.4 (CH_2), 31.7 (CH_2), 29.1 (2 CH_2), 25.6 (CH_2), 22.4 (CH_2), 15.1 (CH_3), 14.2 (CH_3), 13.9 (CH_3) ppm. MS (EI): m/z (%) = 256 (8), 211 (48), 183 (8), 165 (9), 153 (18), 143 (52), 139 (88), 125 (30), 113 (77), 103 (70), 97 (76), 85 (100), 73 (51), 70 (82), 57 (98). HRMS: m/z calcd. for $C_{15}H_{28}O_3$ $[M^+]$ 256.2038; found 256.2028.

(2*R,6*S**)-11c:** IR (film): $\tilde{\nu}_{max}$ = 2957 (s), 2929 (s), 2872 (s), 2859 (s), 1729 (w), 1674 (m), 1459 (m), 1380 (m), 1335 (w), 1308 (w), 1290 (w), 1269 (w), 1201 (s), 1121 (s), 1105 (s), 1064 (s), 1041 (s), 960 (m), 949 (m), 817 (w), 786 (m), 734 (w), 722 (w) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.81 (s, 1 H, 2-H), 4.73 (t, $^{3}J_{H,H}$ = 3.6 Hz, 1 H, 4-H), 3.96–3.90 (m, 1 H, 6-H), 3.88–3.80 (m, 1 H, 1 H of CH_2 of OEt), 3.79–3.67 (m, 2 H, CH_2 of OEt), 3.62–3.54 (m, 1 H, 1 H of CH_2 of OEt), 2.01–1.99 (m, 2 H, 5-H), 1.48–1.45 (m, 2 H, CH_2 of hexyl), 1.29 (m, 11 H, CH_3 of OEt and 4 CH_2 of hexyl), 1.26 (t, $^{3}J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt), 0.89 (m, 3 H, CH_3 of hexyl) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 151.5 (C), 95.0 (CH), 94.1 (CH), 66.8 (CH), 63.0 (CH_2), 62.2 (CH_2), 35.1 (CH_2), 31.7 (CH_2), 29.5 (CH_2), 29.1 (CH_2), 25.6 (CH_2), 22.5 (CH_2), 15.1 (CH_3), 14.3 (CH_3), 13.9 (CH_3) ppm. MS (EI): m/z (%) = 256 (10), 225 (12), 211 (63), 199 (52), 180 (70), 165 (18), 151 (51), 143 (62), 133 (43), 123 (85), 110 (86), 97 (98), 85 (100), 70 (91), 53 (72). HRMS: m/z calcd. for $C_{15}H_{28}O_3$ $[M^+]$ 256.2038; found 256.2017.

2,3-Diethoxy-6-phenyl-5,6-dihydro-2*H*-pyran [(2*R,6*R**/6*S**)-11d]:** The compound, 0.076 g (61% yield), was obtained as a yellowish liquid over two steps from 4,4,5,5-tetraethoxy-1-phenyl-2-pentyn-1-ol.[8] Pure samples of the *cis* (2*R**,6*S**)-**11d** and *trans* (2*R**,6*R**)-**11d** isomers were isolated by flash chromatography (hexane/ethyl acetate in a 92.5:7.5 ratio). From the ^{1}H NMR spectrum of the crude product mixture the *cis*/*trans* ratio was determined to be 68:32.

(2*R,6*S**)-11d:** IR (film): $\tilde{\nu}_{max}$ = 3062 (m), 3031 (m), 2977 (s), 2922 (s), 2895 (s), 1669 (s), 1482 (m), 1449 (m), 1378 (m), 1330 (m), 1280 (m), 1214 (s), 1181 (s), 1121 (s), 1070 (s), 942 (m), 896 (w), 790 (w), 755 (m), 700 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 7.41–7.23 (m, 5 H, phenyl), 5.32 (t, $^{3}J_{H,H}$ = 2.0 Hz, 1 H, 2-H), 4.92 (dd, $^{3}J_{H,H}$ = 2.0, $^{3}J_{H,H}$ = 6.6 Hz, 1 H, 4-H), 4.71 (dd, $^{3}J_{H,H}$ = 3.4, $^{3}J_{H,H}$ = 10.5 Hz, 1 H, 6-H), 3.86–3.67 (m, 4 H, 2 CH_2 of 2 OEt), 2.43 (ddd, $^{3}J_{H,H}$ = 2.0, $^{3}J_{H,H}$ = 10.5, $^{2}J_{H,H}$ = 16.0 Hz, 1 H, 5-H), 2.27 (ddd, $^{3}J_{H,H}$ = 3.4, $^{3}J_{H,H}$ = 6.6, $^{2}J_{H,H}$ = 16.0 Hz, 1 H, 5-H), 1.33 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt), 1.26 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 151.4 (C), 141.5 (C), 128.0 (2 CH), 127.2 (CH), 125.5 (2 CH), 96.9 (CH), 95.3 (CH), 74.3 (CH), 62.5 (CH_2), 62.1 (CH_2), 31.3 (CH_2), 15.2 (CH_3), 14.2 (CH_3) ppm. MS (EI): m/z (%) = 248 (1), 203 (38), 173

(18), 157 (73), 143 (81), 127 (78), 113 (93), 104 (84), 91 (100), 86 (98), 77 (83), 70 (77), 55, (68). HRMS: *m/z* calcd. for $C_{13}H_{15}O_2$ ([M – OEt]$^+$) 203.1072, 203.1066.

(2*R,6*R**)-11d:** IR (film): $\tilde{\nu}_{max}$ = 3061 (m), 3033 (m), 2975 (s), 2901 (s), 1726 (w), 1673 (s), 1605 (w), 1493 (m), 1449 (m), 1383 (m), 1335 (m), 1282 (m), 1209 (m), 1103 (s), 1061 (m), 975 (m), 912 (m), 888 (m), 812 (m), 789 (m), 754 (s), 700 (s), 674 (w), 639 (w), 576 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 7.41–7.25 (m, 5 H), 5.02 (dd, $^3J_{H,H}$ = 4.3, $^3J_{H,H}$ = 10.7 Hz, 1 H, 6-H), 5.00 (s, 1 H, 2-H), 4.85 (dd, $^3J_{H,H}$ = 2.5, $^3J_{H,H}$ = 5.6 Hz, 1 H, 4-H), 3.89–3.72 (m, 3 H, 3 H of CH_2 of 2 OEt), 3.67–3.59 (m, 1 H, 1 H of CH_2 of OEt), 2.38 (m, $^3J_{H,H}$ = 10.7, $^2J_{H,H}$ = 16.6 Hz, 1 H, 5-H), 2.31 (m, $^3J_{H,H}$ = 5.6, $^2J_{H,H}$ = 16.6 Hz, 1 H, 5-H), 1.33 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt), 1.25 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 151.6 (C), 141.7 (C), 128.2 (2 CH), 127.3 (CH), 125.9 (2 CH), 95.5 (CH), 94.3 (CH), 68.9 (CH), 63.5 (CH_2), 62.5 (CH_2), 31.1 (CH_2), 15.3 (CH_3), 14.3 (CH_3) ppm. MS (EI): *m/z* (%) = 248 (2), 203 (78), 175 (30), 157 (92), 143 (88), 129 (81), 113 (100), 104 (86), 86 (95), 77 (83), 70 (77), 55 (68). HRMS: *m/z* calcd. for $C_{13}H_{15}O_2$ ([M – OEt]$^+$) 203.1072; found 203.1078.

2,3-Diethoxy-6,6-dimethyl-3,6-dihydro-2*H*-pyran (11e): The compound, 0.055 g (55% yield), was obtained as a yellowish liquid over two steps from 5,5,6,6-tetraethoxy-2-methyl-3-hexyn-2-ol.[8] Purification was performed by flash chromatography (hexane/ethyl acetate in a 90:10 ratio). IR (film): $\tilde{\nu}_{max}$ = 2975 (s), 2928 (s), 2891 (s), 1678 (s), 1446 (m), 1378 (s), 1336 (m), 1311 (m), 1271 (m), 1217 (m), 1112 (s), 1065 (s), 1034 (s), 963 (m), 901 (w), 874 (w), 790 (w), 750 (w) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.89 (s, 1 H, 2-H), 4.72 (dd, $^3J_{H,H}$ = 3.1, $^3J_{H,H}$ = 5.6 Hz, 1 H, 4-H), 3.90–3.69 (m, 3 H, 3 H of CH_2 of 2 OEt), 3.61–3.53 (m, 1 H, 1 H of CH_2 of OEt), 2.22 (br. d, $^2J_{H,H}$ = 16.4 Hz, 1 H, 5-H), 2.06 (dd, $^3J_{H,H}$ = 5.6, $^2J_{H,H}$ = 16.4 Hz, 1 H, 5-H), 1.37 (s, 3 H, 6-Me), 1.32 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt), 1.27 (s, 3 H, 2-Me), 1.24 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 150.2 (C), 94.3 (CH), 92.9 (CH), 71.0 (C), 62.6 (CH_2), 62.2 (CH_2), 35.3 (CH_2), 29.5 (CH_3), 26.9 (CH_3), 15.0 (CH_3), 14.2 (CH_3) ppm. MS (EI): *m/z* (%) = 200 (75), 185 (45), 155 (83), 143 (68), 139 (72), 124 (65), 115 (78), 110 (75), 103 (98), 95 (78), 83 (87), 79 (84), 75 (63), 67 (100), 59 (83), 53 (86). HRMS: *m/z* calcd. for $C_9H_{15}O_2$ ([M – OEt]$^+$) 155.1072; found 155.1074.

2,3-Diethoxy-1-oxaspiro[5.5]undec-3-ene (11f): The compound, 0.091 g (76% yield), was obtained as a colourless liquid over two steps from 1-(3,3,4,4-tetraethoxybut-1-ynyl)cyclohexanol (**1f**) (vide supra). Purification was carried out by flash chromatography (hexane/ethyl acetate in a 90:10 ratio). IR (film): $\tilde{\nu}_{max}$ = 3057 (w), 2930 (s), 1679 (m), 1446 (m), 1381 (m), 1340 (m), 1249 (m), 1208 (m), 1151 (m), 1105 (s), 1067 (s), 847 (s), 892 (m), 867 (m), 790 (m), 742 (m), 655 (w) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.90 (s, 1 H, 2-H), 4.70 (dd, $^3J_{H,H}$ = 3.6, $^3J_{H,H}$ = 5.0 Hz, 1 H, 4-H), 4.04–3.50 (m, 4 H, 2 CH_2 of 2 OEt), 2.25–2.04 (m, 2 H, 5-H), 2.03–1.94 (m, 4 H, 2 CH_2 of cyclohexyl), 1.70–1.37 (m, 6 H, 3 CH_2 of cyclohexyl), 1.31 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt), 1.25 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 150.1 (C), 94.1 (CH), 92.7 (CH), 72.6 (C), 63.3 (CH_2), 62.3 (CH_2), 38.0 (CH_2), 35.3 (CH_2), 33.9 (CH_2), 25.9 (CH_2), 22.3 (CH_2), 22.2 (CH_2), 15.0 (CH_3), 14.3 (CH_3) ppm. MS (EI): *m/z* (%) = 240 (4), 239 (30), 181 (100), 153 (33), 135 (97), 117 (38), 103 (94), 89 (75), 75 (82), 67 (40), 59 (62). HRMS: *m/z* calcd. for $C_{14}H_{24}O_3$ [M$^+$] 240.1725; found 240.1717.

1-Iodoperfluorobutylation of 11b–11f: All the reactions were performed following the general procedure used to carry out 1-iodoperfluoroalkylation of **11a** (vide supra). The following products were obtained.

2-Ethoxy-6-methyl-4-(perfluorobutyl)tetrahydropyran-3-one [(2*R,4*R**/4*S**,6*R**)-12b-I]:** The compound was prepared from (2*R**,6*R**)-**11b** (0.19 g, 1.0 mmol). Evaporation of the solvent gave 0.30 g (78%) of (2*R**,4*R**/4*S**,6*R**)-**12b-I** as a yellowish liquid. The compound was obtained as a 42:58 mixture of the (4*R**/4*S**) diastereomers according to ^{1}H NMR spectra of the crude product. IR (film): $\tilde{\nu}_{max}$ = 3498 (w), 2981 (s), 2936 (s), 2908 (s), 1755 (s), 1675 (w), 1451 (m), 1381 (m), 1350 (m), 1294 (m), 1210 (s), 1133 (s), 1065 (s), 947 (m), 906 (m), 881 (m), 841 (m), 739 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.81 and 4.79 (2s in a 58:42 ratio, 1 H, 2-H), 4.28–4.22 (major) and 4.22–4.15 (minor) (m, 1 H, 6-H), 3.96–3.87 (m, 1 H, 1 H of CH_2 of OEt), 3.77–3.71 and 3.44–3.32 (m, 1 H, 4-H), 3.68–3.59 (m, 1 H, 1 H of CH_2 of OEt), 2.47–2.40 (m, 1 H, 5-H), 2.35–2.20 (m, 1 H, 5-H), 1.42 (major, $^3J_{H,H}$ = 6.5 Hz) and 1.39 (minor, $^3J_{H,H}$ = 6.2 Hz) (d, 3 H, 6-Me), 1.27 (major) and 1.26 (minor) (2 overlapping t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 195.2 (major) and 193.6 (minor) (C), 99.9 (major) and 99.3 (minor) (CH), 69.8 (minor) and 67.8 (major) (CH), 64.7 (major) and 64.6 (minor) (CH_2), 48.0 (minor, t, *J* = 21.3 Hz), 45.2 (major, t, *J* = 21.3 Hz) (CH), 32.2 (major) and 30.7 (minor) (CH_2), 22.0 (minor) and 21.3 (major) (CH_3), 14.8 (minor) and 14.7 (major) (CH_3) ppm. MS (EI): *m/z* (%) = 376 (18), 330 (10), 301 (22), 157 (13), 133 (19), 103 (100), 75 (65). HRMS: *m/z* calcd. for $C_{12}H_{13}O_3F_9$ [M$^+$] 376.0721, 376.0705.

2-Ethoxy-6-methyl-4-(perfluorobutyl)tetrahydropyran-3-one [(2*R,4*R**/4*S**,6*S**)-12b-I]:** The compound was prepared from (2*R**,6*S**)-**11b** (0.19 g, 1.0 mmol). Evaporation of the solvent gave 0.38 g (99%) of (2*R**,4*R**/4*S**,6*S**)-**12b-I** as a yellow liquid. The compound was obtained as a 60:40 mixture of the (4*R**/4*S**) diastereoisomers according to ^{1}H NMR spectra of the crude product. IR (film): $\tilde{\nu}_{max}$ = 2982 (s), 2936 (s), 1756 (s), 1674 (w), 1452 (m), 1384 (m), 1351 (s), 1209 (s), 1133 (s), 1053 (s), 958 (m), 904 (m), 811 (m), 734 (m), 696 (m), 652 (m) cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si): δ = 4.77 and 4.67 (2s in a 40:60 ratio, 1 H, 2-H), 4.51–4.44 (major) and 4.44–4.35 (minor) (2m, 1 H, 6-H), 3.93–3.85 (major) and 3.52–3.41 (minor) (2m, 1 H, 4-H), 3.88–3.78 (m, 1 H, 1 H of CH_2 of OEt), 3.65–3.56 (m, 1 H, 1 H of CH_2 of OEt), 2.39–2.30 (m, 1 H, 5-H), 2.18–2.10 (minor) and 2.04–1.94 (major) (2m, 1 H, 5-H), 1.31 (minor) and 1.29 (major) (2d, $^3J_{H,H}$ = 6.3 Hz, 3 H, 6-Me), 1.27 (major) and 1.26 (minor) (2t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 195.8 (minor) and 194.4 (major) (C), 99.7 (major) and 98.6 (minor) (CH), 64.4 (major) and 63.1 (minor), (CH), 64.3 (minor) and 64.0 (major) (CH_2), 46.0 (major, t, *J* = 21.3 Hz) and 45.8 (minor, t, *J* = 21.3 Hz) (CH), 35.6 (major) and 30.9 (minor) (CH_2), 20.8 (minor) and 20.2 (major) (CH_3), 14.9 (major) and 14.7 (minor) (CH_3) ppm. MS (EI): *m/z* (%) = 375 (4), 359 (22), 348 (48), 331 (38), 311 (81), 301 (32), 283 (91), 265 (72), 254 (76), 240 (88), 215 (62), 163 (83), 145 (82), 107 (88), 69 (100). HRMS: *m/z* calcd. for $C_{12}H_{13}O_3F_9$ [M$^+$] 376.0721; found 376.0696.

2-Ethoxy-6-hexyl-4-(perfluorobutyl)tetrahydropyran-3-one [(2*R,4*R**/4*S**,6*R**)-12c-I]:** The compound was prepared from (2*R**,6*R**)-**11c** (0.13 g, 0.51 mmol). Evaporation of the solvent gave 0.18 g (77%) of (2*R**,4*R**/4*S**,6*R**)-**12c-I** as a yellowish liquid. The compound was obtained as a 55:45 mixture of the (4*R**/4*S**) diastereoisomers according to ^{1}H NMR spectra of the crude product. IR (film): $\tilde{\nu}_{max}$ = 2931 (s), 2958 (s), 2860 (m), 1755 (m), 1681 (m), 1651 (w), 1644 (w), 1519 (w), 1467 (m), 1460 (m), 1379 (m), 1353 (m), 1296 (w), 1236 (s), 1221 (s), 1136 (s), 1119 (s), 1056 (s), 878 (w), 842 (w), 792 (w), 739 (w), 695 (w), 665 (w) cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, Me_4Si): δ = 4.80 and 4.76 (2s in a 55:45 ratio, 1 H, 2-H), 4.00–3.28 (m, 4 H, CH_2 of OEt, 6-H and 4-H), 2.37–2.22 (m, 1 H, 5-H), 2.13–2.00 (m, 1 H, 5-H), 1.71–1.27 (m, 10 H, 5 CH_2 of hexyl), 1.26 and 1.25 (2t, $^3J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt), 0.89–0.87 (m, 3 H, CH_3 of hexyl) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 195.4 and 193.7 (C), 99.8 and 99.3 (CH), 73.6 and 72.7 (CH), 65.0 and, 64.7 (CH_2), 48.0 and 45.6 (t, J = 21.6 Hz, CH), 35.6 and 35.2 (CH_2), 31.8 and 31.7 (CH_2), 29.2 and 29.0 (CH_2), 25.8 and 25.7 (CH_2), 25.5 (CH_2), 22.6 and 22.5 (CH_2), 15.2 and 14.9 (CH_3), 13.9 (CH_3) ppm. MS (EI): m/z (%) = 446 (72), 430 (21), 417 (81), 402 (30), 389 (64), 371 (100). HRMS: m/z calcd. for $C_{17}H_{23}O_3F_9$ [M^+] 446.1503; found 446.1495.

2-Ethoxy-6-hexyl-4-(perfluorobutyl)tetrahydropyran-3-one [(2R*,4R*/4S*,6S*)-12c-I]: The compound was prepared from (2R*,6S*)-**11c** (0.26 g, 1.01 mmol). Evaporation of the solvent gave 0.39 g (86%) of (2R*,4R*/4S*,6S*)-**12c-I** as a yellowish liquid. The compound was obtained as a 65:35 mixture of the (4R*/4S*) diastereoisomers according to ^1H NMR spectra of the crude product. IR (film): $\tilde{\nu}_{max}$ = 2933 (s), 2958 (s), 2861 (m), 1759 (m), 1685 (w), 1467 (m), 1460 (m), 1353 (m), 1292 (m), 1236 (s), 1171 (m), 1135 (s), 1111 (m), 1048 (m), 923 (w), 881 (w), 816 (w), 744 (w), 729 (w), 696 (w), 665 (w) cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, Me_4Si): δ = 4.79 and 4.68 (2s in a 35:65 ratio, 1 H, 2-H), 4.29–4.22 (major) and 4.22–4.14 (minor) (2m, 1 H, 6-H), 4.01–3.95 and 3.54–3.42 (2m, 1 H, 4-H), 3.93–3.76 (m, 1 H, 1 H of CH_2 of OEt), 3.67–3.54 (m, 1 H, 1 H of CH_2 of OEt), 2.35–2.13 (m, 2 H, 5-H), 1.64–1.18 (m, 10 H, 5 CH_2 of hexyl), 1.26 (major) and 1.25 (minor) (2 partly overlapping t, $^3J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt), 0.89 (m, 3 H, CH_3 of hexyl) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 196.6 (minor) and 194.6 (major) (C), 99.6 (major) and, 98.5 (minor) (CH), 67.9 (major) and 66.8 (minor) (CH), 64.1 (minor) and 63.8 (major) (CH_2), 46.0 (major, t, J = 20.1 Hz) and 45.8 (minor, t, J = 20.1 Hz) (CH), 35.3 (minor) and 34.6 (major) (CH_2), 34.0 (CH_2), 31.7 (CH_2), 29.1 (major) and 29.0 (minor) (CH_2), 25.5 (major) and 25.4 (minor) (CH_2), 22.5 (CH_2), 14.9 (major) and 14.7 (minor) (CH_3), 13.9 (CH_3) ppm. MS (EI): m/z (%) = 445 (3), 405 (6), 381 (8), 352 (58), 310 (69), 296 (78), 281 (72), 262 (67), 254 (35), 226 (36), 207 (18), 183 (71), 163 (65), 143 (74), 113 (68), 107 (76), 95 (83), 69 (84), 57 (100). HRMS: m/z calcd. for $C_{17}H_{22}O_3F_9$ ($[M-H]^+$) 445.1425; found 445.1414.

2-Ethoxy-4-(perfluorobutyl)-6-phenyltetrahydropyran-3-one [(2R*,4R*/4S*,6S*)-12d-I]: The compound was prepared from (2R*,6S*)-**11d** (0.26 g, 1.0 mmol). Evaporation of the solvent gave 0.43 g (95%) of (2R*,4R*/4S*,6S*)-**12d-I** as a yellowish liquid. The compound was obtained as a 50:50 mixture of the (4R*/4S*) diastereoisomers according to ^1H NMR spectra of the crude product. IR (film): $\tilde{\nu}_{max}$ = 3067 (w), 3035 (w), 2981 (s), 2933 (s), 2902 (m), 1755 (s), 1677 (m), 1497 (w), 1453 (m), 1376 (m), 1352 (m), 1294 (m), 1240 (s), 1135 (s), 1055 (s), 949 (w), 911 (w), 883 (w), 845 (w), 827 (w), 761 (m), 738 (m), 700 (m) cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, Me_4Si): δ = 7.44–7.30 (m, 5 H, phenyl), 5.14 ($^3J_{H,H}$ = 4.6, $^3J_{H,H}$ = 9.6 Hz) and 5.04 ($^3J_{H,H}$ = 2.9, $^3J_{H,H}$ = 11.7 Hz) (2dd in a 1.0:1.0 ratio, 1 H, 6-H), 5.04 and 4.94 (2s in a 1.0:1.0 ratio, 1 H, 2-H), 4.01–3.50 (m, 3 H, CH_2 of OEt and 4-H), 2.73–2.46 (m, 2 H, 5-H), 1.25 and 1.24 (2t in a 1.0:1.0 ratio, $^3J_{H,H}$ = 7.2 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 194.7 and 193.0 (C), 139.9 (C), 128.6 (2 CH), 128.3 (CH), 126.1 (2 CH), 99.9 and 99.5 (CH), 75.4 and 73.1 (CH), 65.3 and 65.1 (CH_2), 48.3 and 46.8 (2t, J = 21.4 Hz, CH), 32.5 and 31.5 (CH_2), 14.7 (CH_3) ppm. MS (EI): m/z (%) = 438 (2), 360 (73), 323 (5), 253 (100), 225 (75), 207 (36), 177 (22), 157 (44), 146 (36), 105 (93), 77 (52).

2-Ethoxy-4-(perfluorobutyl)-6-phenyltetrahydropyran-3-one [(2R*,4R*/4S*,6R*)-12d-I]: The compound was prepared from (2R*,6R*)-**11d** (0.26 g, 1.0 mmol). Evaporation of the solvent gave 0.42 g (93%) of (2R*,4R*/4S*,6R*)-**12d-I** as a yellowish liquid. The compound was obtained as a 70:30 mixture of the (4R*/4S*) diastereoisomers according to ^1H NMR spectra of the crude product. IR (film): $\tilde{\nu}_{max}$ = 3092 (w), 3066 (w), 3035 (w), 2981 (m), 2932 (m), 2903 (m), 1755 (m), 1497 (w), 1455 (w), 1353 (m), 1295 (m), 1236 (s), 1171 (m), 1135 (s), 1109 (m), 1047 (s), 1028 (m), 030 (w), 912 (w), 892 (w), 880 (w), 867 (w), 844 (w), 802 (w), 791 (w), 759 (m), 745 (m), 731 (m), 699 (m) cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 7.40–7.31 (m, 5 H, phenyl), 5.39–5.26 (m, 1 H, 6-H), 4.96 and 4.86 (2s in a 30:70 ratio, 1 H, 2-H), 4.13–3.50 (m, 3 H, CH_2 of OEt and 4-H), 2.66–2.28 (m, 2 H, 5-H), 1.28 (major) and 1.27 (minor) (2 partly overlapping t, $^3J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 195.2 (minor) and 194.0 (major) (C), 139.0 (C), 128.7 (2 CH), 128.4 (CH), 126.1 (2 CH), 100.0 (major) and 99.9 (minor) (CH), 70.3 (minor) and 70.2 (major) (CH), 64.3 (major) and 64.0 (minor) (CH_2), 46.2 (2t, J = 21.3 Hz, CH), 36.2 (CH_2), 14.9 (CH_3) ppm. MS (EI): m/z (%) = 437 (2), 373 (60), 344 (93), 324 (81), 283 (72), 264 (54), 205 (63), 175 (82), 146 (92), 115 (100), 77 (92).

2-Ethoxy-6,6-dimethyl-4-(perfluorobutyl)tetrahydropyran-3-one [(2R*,4R*/4S*)-12e-I]: The compound was prepared from (2R*)-**11e** (2.00 g, 10 mmol). Evaporation of the solvent gave 3.74 g (96%) of (2R*,4R*/4S*)-**12e-I** as a yellowish liquid. The compound was obtained as a 84:16 mixture of the (4R*/4S*) diastereoisomers according to ^1H NMR spectra of the crude product. IR (film): $\tilde{\nu}_{max}$ = 3500 (m) 2981 (s), 2935 (s), 1757 (s), 1453 (m), 1375 (m), 1350 (m), 1319 (m), 1232 (s), 1133 (s), 1055 (s), 938 (w), 880 (m), 813 (w), 742 (m), 717 (m) cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, Me_4Si): δ = 4.71 and 4.68 (2s in a 16:84 ratio, 1 H, 2-H), 4.07–3.95 (major) and 3.61–3.56 (2m, 1 H, 4-H), 3.93–3.86 (m, 1 H, 1 H of CH_2 of OEt), 3.60–3.52 (m, 1 H, 1 H of CH_2 of OEt), 2.32 (dd, $^3J_{H,H}$ = 4.6, $^2J_{H,H}$ = 13.5 Hz, 1 H, 5-H), 2.22 (t, $^2J_{H,H}$ = $^3J_{H,H}$ = 13.5 Hz, 1 H, 5-H), 1.62 (s, 3 H, 6-Me), 1.34 (s, 3 H, 6-Me), 1.25 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 195.1 (major) and 194.8 (minor) (C), 99.6 (major) and 98.6 (minor) (CH), 73.0 (minor) and 72.8 (major) (C), 64.6 (minor) and 64.1 (major) (CH_2), 44.7 (minor, t, J = 21.3 Hz) and 43.0 (major, t, J = 21.3 Hz) (CH), 38.6 (CH_2), 30.8 (CH_3), 27.3 (minor) and 26.3 (major) (CH_3), 14.5 (minor) and 14.6 (major) (CH_3) ppm. MS (EI): m/z (%) = 390 (60) [M^+], 371 (33), 361 (48), 343 (41), 329 (100), 315 (54), 299 (50), 287 (44), 149 (42), 103 (38). HRMS: m/z calcd. for $C_{13}H_{15}O_3F_9$ [M^+] 390.0877; found 390.0864.

2-Ethoxy-4-(perfluorobutyl)-1-oxaspiro[5.5]undec-3-one [(2R*,4R*/4S*)-12f-I]: The compound was prepared from (2R*)-**11f** (2.80 g, 11.7 mmol). Evaporation of the solvent gave 4.54 g (91%) of (2R*,4R*/4S*)-**12f-I** as a yellowish liquid. The compound was obtained as a 80:20 mixture of the (4R*/4S*) diastereoisomers according to ^1H NMR spectra of the crude product. IR (film): $\tilde{\nu}_{max}$ = 3529 (m), 2936 (s), 2975 (s), 1755 (m), 1450 (m), 1349 (m), 1306 (m), 1217 (s), 1131 (s), 1069 (s), 974 (m), 916 (m), 857 (m), 810 (m), 740 (m), 701 (m) cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.74 and 4.72 (2s in a 1.0:4.0 ratio, 1 H, 2-H), 4.00–3.94 and 3.42–3.31 (2m, 1 H, 4-H), 3.97–3.88 (m, 1 H, 1 H of CH_2 of OEt), 3.64–3.54 (m, 1 H, 1 H of CH_2 of OEt), 2.43 (dd, $^3J_{H,H}$ = 4.3, $^2J_{H,H}$ = 13.6 Hz, 1 H, 5-H), 2.04 (t, $^2J_{H,H}$ = $^3J_{H,H}$ = 13.6 Hz, 1 H, 5-H), 1.96–1.32 (m, 10 H, 5 CH_2 of cyclohexyl), 1.25 (t, $^3J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 195.6 (major) and 195.2 (minor) (C), 99.6 (major) and 99.1 (minor) (CH), 74.0 (major) and 73.4 (minor) (C), 65.1 (major) and 64.8 (minor) (CH_2), 58.3 (major) and 55.7 (minor) (CH_2), 44.5 (minor, t, *J* = 21.5 Hz) and 42.8 (major, t, *J* = 21.5 Hz) (CH), 39.8 (minor) and 39.4 (major) (CH_2), 36.0 (minor) and 35.4 (major) (CH_2), 25.6 (major) and 25.4 (minor) (CH_2), 22.4 (minor) and, 22.3 (major) (CH_2), 22.2 (major), 22.0 (minor) (CH_2), 14.9 (minor) and 14.8 (major) (CH_3) ppm. MS (EI): *m*/*z* (%) = 430 (100) [M^+], 385 (27), 367 (31), 339 (21), 327 (7), 239 (83), 158 (63), 129 (43), 103 (62), 81 (63). HRMS: *m*/*z* calcd. for $C_{16}H_{19}O_3F_9$ [M^+] 430.1190; found 430.1185.

Synthesis of 2-Ethoxy-4-(perfluorobutyl)tetrahydropyran-3-ols 8b-I–8f-I: The reactions were carried out by reduction of 2-ethoxy-4-(perfluorobutyl)tetrahydropyran-3-ones **12b-I**–**12f-I** as described for the conversion of **12a-I** to **8a-I** (vide supra). The products were obtained as isomer mixtures, and flash chromatography, using hexane/ethyl acetate mixtures as eluents, was used in attempts to isolate pure samples of all the isomers. This was not always successful due to the very similar R_f values for some of the isomers. The solvent ratio used is given below for each of the compounds.

2-Ethoxy-6-methyl-4-(perfluorobutyl)tetrahydropyran-3-ol [(2*R,3*R**/3*S**,4*R**/4*S**,6*R**)-8b-I]:** The compound was prepared from 0.25 g (0.66 mmol) of (2*R**,4*R**/4*S**,6*R**)-**12b-I** with a 4*R**/4*S** ratio of 58:42. Solvent evaporation gave 0.20 g (81%) of (2*R**,3*R**/3*S**,4*R**/4*S**,6*R**)-**8b-I** as a yellowish liquid consisting of a mixture of three pairs of diastereomers. The isomeric composition was determined by ^1H NMR investigations of the product mixture before isolation of the major isomers started, using the integrals of the anomeric protons to determine the isomeric composition. The anomeric protons showed the following chemical shifts and relative intensities: 4.82 ppm, 10% (3*R**,4*S**); 4.70 ppm, 42% (3*S**,4*R**); 4.39 ppm, 48% (3*S**,4*S**); no signal due to the (3*R**,4*R**) isomer was observed. Separation and purification were carried out by flash chromatography (hexane/ethyl acetate in a 90:10 ratio), and the two diastereomeric pairs with a *cis* relationship between the OH and OEt groups were isolated pure.

(2*R,3*S**,4*S**,6*R**)-8b-I:** IR (film): $\tilde{\nu}_{max}$ = 3499 (m), 2981 (s), 2937 (s), 2877 (s), 1449 (m), 1378 (m), 1351 (m), 1328 (m), 1285 (m), 1236 (s), 1134 (s), 1098 (m), 1066 (m), 1041 (m), 966 (m), 940 (m), 910 (m), 893 (m), 880 (m), 857 (m), 804 (m), 734 (m), 717 (m), 698 (w), 673 (w) 619 (m) cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.39 (d, $^3J_{H,H}$ = 0.8 Hz, 1 H, 2-H), 4.04 (br. s, 1 H, 3-H), 4.01–3.94 (m, 1 H, 1 H of CH_2 of OEt), 3.65–3.52 (m, 2 H, 1 H of CH_2 of OEt and 6-H), 2.46–2.32 (m, 1 H, 4-H), 2.37 (d, $^3J_{H,H}$ = 2.7 Hz, 1 H, OH), 1.86 (m, 1 H, 5-H), 1.63 (br. d, $^2J_{H,H}$ = 13.2 Hz, 1 H, 5-H), 1.32 (d, $^3J_{H,H}$ = 6.2 Hz, 3 H, 6-Me), 1.25 (t, $^3J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 100.2 (CH), 70.3 (CH), 64.5 (CH_2), 63.5 (CH), 41.5 (t, *J* = 20.8 Hz, CH), 25.8 (CH_2), 21.0 (CH_3), 15.0 (CH_3) ppm. MS (EI): *m*/*z* (%) = 378 (2), 359 (4), 333 (68), 317 (30), 303 (47), 286 (34), 274 (52), 255 (69), 226 (54), 206 (52), 145 (42), 103 (77), 69 (98), 57 (100). HRMS: *m*/*z* calcd. for $C_{10}H_{10}O_2F_9$, ([M – OEt]$^+$) 333.0537; found 333.0545.

(2*R,3*S**,4*R**,6*R**)-8b-I:** IR (film): $\tilde{\nu}_{max}$ = 3445 (m), 2979 (s), 2934 (s), 1448 (m), 1381 (m), 1354 (m), 1326 (m), 1303 (m), 1233 (s), 1168 (s), 1135 (s), 1108 (s), 1070 (s), 1025 (s), 975 (s), 951 (m), 892 (s), 951 (m), 892 (s), 866 (m), 840 (w), 821 (w), 799 (w), 766 (m), 748 (m), 728 (m), 701 (m), 689 (w), 663 (w), 650 (w) cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.70 (d, $^3J_{H,H}$ = 2.3 Hz, 1 H, 2-H), 4.23–4.19 (m, 1 H, 6-H), 4.02 (br. s, 1 H, 3-H), 3.92–3.84 (m, 1 H, 1 H H of CH_2 of OEt), 3.55–3.48 (m, 1 H, 1 H of CH_2 of OEt), 3.08–2.96 (m, 1 H, 4-H), 2.41–2.33 (m, 1 H, 5-H), 2.29–2.19 (m, 1 H, 5-H), 1.57 (br. d, $^3J_{H,H}$ = 13.7 Hz, 1 H, OH), 1.38 (d, $^3J_{H,H}$ = 6.9 Hz, 3 H, 6-Me), 1.20 (t, $^3J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 99.8 (CH), 67.4 (CH), 65.5 (CH), 63.6 (CH_2), 33.4 (t, *J* = 20.2 Hz, CH), 23.7 (CH_2), 21.6 (CH_3), 14.8 (CH_3) ppm. MS (EI): *m*/*z* (%) = 377 (3), 363 (10), 345 (18), 333 (78), 317 (72), 303 (45), 287 (62), 267 (68), 255 (71), 226 (62), 206 (53), 145 (53), 88 (78), 69 (100), 57 (98). HRMS: *m*/*z* calcd. for $C_{12}H_{15}O_3F_9$ [M^+] 378.0877; found 378.0850.

2-Ethoxy-6-methyl-4-(perfluorobutyl)tetrahydropyran-3-ol [(2*R,3*R**/3*S**,4*R**/4*S**,6*S**)-8b-I]:** The compound was prepared from 0.30 g (0.80 mmol) of (2*R**,4*R**/4*S**,6*S**)-**12b-I** with a 4*R**/4*S** ratio of 40:60. Solvent evaporation gave 0.28 g (93%) of (2*R**,3*R**/3*S**,4*R**/4*S**,6*S**)-**8b-I** as a yellowish liquid consisting of a mixture of four pairs of diastereomers. The isomeric composition was determined by ^1H NMR investigations of the product mixture before isolation of the major isomers started, using the integrals of the anomeric protons to determine the isomeric composition. The anomeric protons showed the following chemical shifts and relative intensities: 4.82 ppm, 76% (3*S**,4*R**); 4.72 ppm, 8% (3*R**,4*R**); 4.68 ppm, 12% (3*S**,4*S**); 4.35 ppm, 4% (3*R**,4*S**). Separation and purification were carried out by flash chromatography (hexane/ethyl acetate in a 90:10 ratio), and the two diastereomeric pairs with a *trans* relationship between the perfluorobutyl and OEt groups were isolated pure.

(2*R,3*S**,4*R**,6*S**)-8b-I:** IR (film): $\tilde{\nu}_{max}$ = 3566 (m), 3491 (m), 2980 (s), 2937 (m), 2907 (m), 1450 (m), 1388 (m), 1353 (s), 1291 (m), 1236 (s), 1135 (s), 1039 (s), 1058 (s), 1000 (m), 956 (m), 919 (m), 881 (m), 785 (w), 747 (m), 732 (m), 710 (w), 699 (w), 642 (w) cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, Me_4Si): δ = 4.82 (d, $^3J_{H,H}$ = 3.6 Hz, 1 H, 2-H), 3.96–3.88 (m, 1 H, 6-H), 3.87–3.78 (m, 2 H, 1 H of CH_2 of OEt and 3-H), 3.62–3.52 (m, 1 H, 1 H of CH_2 of OEt), 2.83–2.66 (m, 1 H, 4-H), 2.23 (d, $^3J_{H,H}$ = 11.2 Hz, 1 H, OH), 1.87 (br. d, $^2J_{H,H}$ = 14.2 Hz, 1 H, 5-H), 1.41 (q, $^2J_{H,H}$ = $^3J_{H,H}$ = 12.6 Hz, 1 H, 5-H), 1.26 (t, $^3J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt), 1.19 (d, $^3J_{H,H}$ = 6.2 Hz, 3 H, 6-Me) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 97.7 (CH), 66.3 (CH), 63.4 (CH_2), 63.3 (CH), 41.3 (t, *J* = 20.3 Hz, CH), 30.9 (CH_2), 20.6 (CH_3), 14.8 (CH_3) ppm. MS (EI): *m*/*z* (%) = 367 (62), 355 (87), 333 (60), 327 (61), 255 (64), 93 (58), 88 (58), 59 (100). HRMS: *m*/*z* calcd. for $C_{10}H_{10}O_2F_9$ ([M – OEt]$^+$) 333.0537; found 333.0550.

(2*R,3*R**,4*R**,6*S**)-8b-I:** IR (film): $\tilde{\nu}_{max}$ = 3451 (m), 2980 (s), 2937 (m), 1450 (m), 1388 (m), 1354 (m), 1327 (m), 1286 (m), 1236 (s), 1167 (m), 1134 (s), 1079 (m), 1066 (m), 1021 (m), 985 (m), 952 (w), 917 (w), 895 (m), 857 (w), 788 (m), 748 (w), 733 (m), 716 (w), 696 (w), 690 (w) cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.72 (d, $^3J_{H,H}$ = 1.2 Hz, 1 H, 2-H), 3.98–3.90 (m, 2 H, 3-H and 6-H), 3.79–3.72 (m, 1 H, 1 H of CH_2 of OEt), 3.57–3.49 (m, 1 H, 1 H of CH_2 of OEt), 2.93–2.81 (m, 1 H, 4-H), 2.04 (d, $^3J_{H,H}$ = 8.3 Hz, 1 H, 5-H), 1.82–1.63 (m, 2 H, 1 H of 5-H and OH), 1.24 (d, $^3J_{H,H}$ = 6.3 Hz, 3 H, 6-Me), 1.22 (t, $^3J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 99.0 (CH), 64.0 (CH), 63.8 (CH), 63.0 (CH_2), 37.3 (t, *J* = 20.2 Hz, CH), 26.0 (CH_2), 21.2 (CH_3), 15.0 (CH_3) ppm. MS (EI): *m*/*z* (%) = 389 (100), 380 (35), 375 (51), 371 (28), 354 (19), 342 (33). HRMS: *m*/*z* calcd. for $C_{12}H_{15}O_3F_9$ [M^+] 378.0877; found 378.0890.

2-Ethoxy-6-hexyl-4-(perfluorobutyl)tetrahydropyran-3-ol (2*R,3*R**/3*S**,4*R**/4*S**,6*R**)-8c-I):** The compound was prepared from 0.16 g (0.37 mmol) of (2*R**,4*R**/4*S**,6*R**)-**12c-I** with a 4*R**/4*S** ratio of 45:55. Solvent evaporation gave 0.14 g (86%) of (2*R**,3*R**/3*S**,4*R**/4*S**,6*R**)-**8c-I** as a yellowish liquid consisting of a mixture of four pairs of diastereomers. The isomeric composition was determined by ^1H NMR investigations of the product mixture before isolation of the major isomers started, using the integrals of the anomeric protons to determine the isomeric composition. The anomeric protons showed the following chemical shifts and relative intensities: 4.83 ppm, 27% (3*S**,4*S**); 4.64 ppm, 5% (3*R**,4*R**); 4.69 ppm, 50% (3S*,4R*); 4.54 ppm, 18% (3R*,4S*). Separation and purification were carried out by flash chromatography (hexane/ethyl acetate in a 95:5 ratio), and the two diastereomeric pairs with a *cis* relationship between the OH and OEt groups were isolated pure.

(2R*,3S*,4R*,6R*)-8c-I: IR (film): $\tilde{\nu}_{max}$ = 3424 (br), 2959 (s), 2931 (s), 2874 (s), 2860 (s), 1460 (m), 1380 (m), 1354 (m), 1304 (m), 1236 (s), 1221 (s), 1167 (m), 1135 (s), 1111 (s), 1067 (s), 1019 (s), 977 (w), 916 (w), 842 (w), 817 (w), 796 (w), 789 (w), 748 (m), 730 (m), 704 (w), 688 (w), 650 (w) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.69 (d, $^{3}J_{H,H}$ = 2.8 Hz, 1 H, 2-H), 4.00 (m, 1 H, 3-H), 3.94–3.84 (m, 2 H, 1 H of CH_2 of OEt and 6-H), 3.59–3.50 (m, 1 H, 1 H of CH_2 of OEt), 3.00–2.88 (m, 1 H, 4-H), 2.32–2.20 (m, 2 H, 1 H of 5-H and OH), 1.82–1.57 (m, 1 H, 5-H), 1.36–1.24 (m, 10 H, 5 CH_2 of hexyl), 1.20 (t, $^{3}J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt), 0.91–0.87 (m, 3 H, CH_3 of hexyl) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 100.5 (CH), 71.6 (CH), 66.5 (CH), 64.2 (CH_2), 57.7 (CH_2), 35.5 (CH_2), 34.4 (t, *J* = 20.0 Hz, CH), 31.8 (CH_2), 29.2 (CH_2) 26.5 (CH_2), 22.5 (CH_2) 15.0 (CH_3), 13.9 (CH_3) ppm. MS (EI): *m/z* (%) = 447 (2) [M – 1], 429 (3), 410 (2), 403 (4), 374 (5), 367 (10), 363 (22), 345 (18), 336 (8), 217 (91), 299 (18), 289 (31), 267 (19), 128 (20), 112 (82), 88 (69), 83 (84), 70 (97), 55 (100). HRMS: *m/z* calcd. for $C_{15}H_{20}O_2F_9$ ([M – OEt]$^+$) 403.1320; found 403.1320.

(2R*,3S*,4S*,6R*)-8c-I: IR (film): $\tilde{\nu}_{max}$ = 3499 (br), 2957 (s), 2930 (s), 2859 (s), 1732 (w), 1672 (m), 1480 (m), 1467 (m), 1445 (m), 1379 (m), 1351 (m), 1293 (m), 1234 (s), 1134 (s), 1119 (s), 1067 (s), 965 (w), 941 (m), 902 (w), 883 (w), 858 (w), 804 (w), 789 (m), 734 (m), 720 (m), 698 (w), 589 (w), 665 (w) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.83 (s, 1 H, 2-H), 4.05 (m, 1 H, 3-H), 4.02–3.93 (m, 1 H, 1 H of CH_2 of OEt), 3.85–3.55 (m, 2 H, 1 H of CH_2 of OEt and 6-H), 2.47–2.00 (m, 3 H, 5-H and 4-H), 1.67–1.45 (m, 1 H, OH), 1.37–1.22 (m, 13 H, 5 CH_2 of hexyl and CH_3 of OEt), 0.90–0.87 (m, 3 H, CH_3 of hexyl) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 95.2 (CH), 72.8 (CH), 67.0 (CH), 64.5 (CH_2), 62.6 (CH_2), 41.6 (t, *J* = 21.6 Hz, CH), 35.4 (CH_2), 31.8 (CH_2), 29.3 (CH_2), 25.7 (CH_2), 22.6 (CH_2), 15.3 (CH_3), 14.0 (CH_3) ppm. MS (EI): *m/z* (%) = 447 (3), 429 (4), 403 (22), 374 (28), 356 (30), 336 (62), 317 (88), 299 (72), 289 (82), 267 (40), 241 (28), 207 (30), 137 (60), 128 (66), 116 (88), 84 (100). HRMS: *m/z* calcd. for $C_{15}H_{20}O_2F_9$ ([M – OEt]$^+$) 403.1320; found 403.1317.

2-Ethoxy-6-hexyl-4-(perfluorobutyl)tetrahydropyran-3-ol [(2R*,3R*/3S*,4R*/4S*,6S*)-8c-I]: The compound was prepared from 0.36 g (0.81 mmol) of (2R*,4R*/4S*,6S*)-**12c-I** with a 4R*/4S* ratio of 35:65. Solvent evaporation gave 0.34 g (92%) of (2R*,3R*/3S*,4R*/4S*,6S*)-**8c-I** as a yellowish liquid consisting of a mixture of three pairs of diastereomers. The isomeric composition was determined by ^{1}H NMR investigations of the product mixture before isolation of the major isomers started, using the integrals of the anomeric protons to determine the isomeric composition. The anomeric protons showed the following chemical shifts and relative intensities: 4.83 ppm, 55% (3S*,4R*); 4.73 ppm, 10% (3R*,4R*); 4.67 ppm, 35% (3S*,4S*); no signal due to the (3R*,4S*) isomer was observed. Separation and purification were carried out by flash chromatography (hexane/ethyl acetate in a 95:5 ratio), and all the three diastereomeric pairs were isolated pure.

(2R*,3S*,4S*,6S*)-8c-I: IR (film): $\tilde{\nu}_{max}$ = 3608 (m), 4583 (m), 3564 (m), 2959 (s), 2931 (s), 2960 (s), 1462 (m), 1379 (m), 1351 (m), 1290 (m), 1235 (s), 1168 (m), 1134 (s), 1061 (m), 1031 (m), 805 (w), 728 (w), 711 (w), 665 (w) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.67 (d, $^{3}J_{H,H}$ = 3.7 Hz, 1 H, 2-H), 4.26 (m, 1 H, 3-H), 4.08 (m, 1 H, 1 H of CH_2 of OEt), 3.95–3.84 (m, 1 H, 6-H), 3.65–3.57 (m, 1 H, 1 H of CH_2 of OEt), 2.81 (br. s, 1 H, OH), 2.54–2.40 (m, 1 H, 4-H), 2.15–2.07 (m, 1 H, 5-H), 1.62–1.54 (m, 1 H, 5-H), 1.45–1.25 (m, 10 H, 5 CH_2 of hexyl), 1.25 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt), 0.93–0.87 (m, 3 H, CH_3 of hexyl) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 95.4 (CH), 68.2 (CH), 64.2 (CH), 63.4 (CH_2), 37.3 (t, *J* = 20.6 Hz, CH), 31.8 (CH_2), 29.7 (CH_2), 29.1 (CH_2), 25.6 (CH_2), 25.0 (CH_2), 22.6 (CH_2), 15.0 (CH_3), 14.0 (CH_3) ppm. MS (EI): *m/z* (%) = 447 (3) [M – 1], 403 (27), 382 (66), 367 (58), 363 (32), 345 (47), 336 (38), 317 (82), 313 (61), 289 (73), 167 (53), 241 (28), 207 (25), 195 (22), 128 (67), 110 (63), 95 (73), 85 (100). HRMS: *m/z* calcd. for $C_{15}H_{20}O_2F_9$ ([M – OEt]$^+$) 403.1320; found 403.1328.

(2R*,3S*,4R*,6S*)-8c-I: IR (film): $\tilde{\nu}_{max}$ = 3573 (m), 3491 (m), 2958 (s), 2932 (s), 2875 (s), 2860 (s), 1468 (m), 1459 (m), 1378 (m), 1353 (s), 1287 (m), 1236 (s), 1135 (s), 1060 (s), 928 (m), 879 (m), 785 (w), 745 (m), 732 (m), 707 (w), 665 (w), 642 (w) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.83 (d, $^{3}J_{H,H}$ = 3.8 Hz, 1 H, 2-H), 3.87–3.76 (m, 2 H, 1 H of CH_2 of OEt and 6-H), 3.76–3.70 (m, 1 H, 3-H), 3.60–3.50 (m, 1 H, 1 H of CH_2 of OEt), 2.83–2.64 (m, 1 H, 4-H), 2.15 (d, $^{3}J_{H,H}$ = 11.2 Hz, 1 H, 5-H), 1.86 (m, 1 H, 5-H), 1.51–1.39 (m, 3 H, OH and 1 CH_2 of hexyl), 1.35–1.23 (m, 8 H, 4 CH_2 of hexyl), 1.25 (t, $^{3}J_{H,H}$ = 7.1 Hz, 3 H, CH_3 of OEt), 0.90–0.87 (m, 3 H, CH_3 of hexyl) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 97.5 (CH), 67.1 (CH), 66.5 (CH), 63.3 (CH_2), 41.5 (t, *J* = 20.1 Hz, CH), 35.2 (CH_2), 31.8 (CH_2), 29.4 (CH_2), 29.2 (CH_2), 25.5 (CH_2), 22.6 (CH_2), 14.9 (CH_3), 14.0 (CH_3) ppm. MS (EI): *m/z* (%) = 447 (M-1, 3), 417 (30), 387 (53), 353 (58), 317 (78), 289 (63), 241 (68), 207 (23), 147 (63), 133 (82), 113 (85), 85 (100). HRMS: *m/z* calcd. for $C_{17}H_{24}O_3F_9$ ([M – H]$^+$) 447.1582; found 447.1568.

(2R*,3R*,4R*,6S*)-8c-I: IR (film): $\tilde{\nu}_{max}$ = 3447 (br), 2931 (s), 2859 (m), 1459 (m), 1379 (m), 1354 (m), 1235 (s), 1219 (s), 1167 (m), 1135 (s), 1063 (m), 1020 (m), 976 (w), 928 (w), 917 8 (w), 884 (w), 796 (w), 748 (w), 733 (m), 697 (w), 690 (w), 665 (w) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.73 (d, $^{3}J_{H,H}$ = 1.7 Hz, 1 H, 2-H), 3.98 (br. d, $^{3}J_{H,H}$ = 8.3 Hz, 1 H, 3-H), 3.86–3.70 (m, 2 H, 1 H of CH_2 of OEt and 6-H), 3.62–3.48 (m, 1 H, 1 H of CH_2 of OEt), 2.91 (m, 1 H, 4-H), 2.29–1.60 (m, 3 H, 5-H and OH), 1.48–1.21 (m, 13 H, 5 CH_2 of hexyl and CH_3 of OEt), 0.91–0.87 (m, 3 H, CH_3 of hexyl) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 98.9 (CH), 67.6 (CH), 64.4 (CH), 62.9 (CH_2), 37.5 (t, *J* = 21.1 Hz, CH), 35.7 (CH_2), 31.8 (CH_2), 29.7 (CH_2), 29.2 (CH_2), 25.4 (CH_2), 22.6 (CH_2), 14.9 (CH_3), 14.0 (CH_3) ppm. MS (EI): *m/z* (%) = 448 (22), 447 (100), 442 (25), 431 (22). HRMS: *m/z* calcd. for $C_{17}H_{25}O_3F_9$ [M$^+$] 448.1660; found 448.1630.

2-Ethoxy-4-perfluorobutyl-6-phenyltetrahydropyran-3-ol [(2R*,3R*/3S*,4R*/4S*,6S*)-8d-I]: The compound was prepared from 0.24 g (0.55 mmol) of (2R*,4R*/4S*,6S*)-**12d-I** with a 4R*/4S* ratio of 50:50. Solvent evaporation gave 0.21 g (87%) of (2R*,3R*/3S*,4R*/4S*,6S*)-**8d-I** as a yellowish liquid consisting of a mixture of two pairs of diastereomers. The isomeric composition was determined by ^{1}H NMR investigations of the product mixture before isolation of the major isomers started, using the integrals of the anomeric protons to determine the isomeric composition. The anomeric protons showed the following chemical shifts and relative intensities: 5.01 ppm, 22% (3S*,4R*); 4.58 ppm, 78% (3S*,4S*); no signals due to the (3R*,4R*) and (3R*,4S*) diastereomeric pairs were observed. Separation and purification were carried out by flash chromatography (hexane/ethyl acetate in a 90:10 ratio), and both diastereomeric pairs, with a *cis* relationship between the OH and EtO groups, were isolated pure.

(2R*,3S*,4S*,6S*)-8d-I: IR (film): $\tilde{\nu}_{max}$ = 3500 (m), 2093 (w), 3066 (w), 3034 (w), 2980 (m), 2932 (m), 2874 (m), 1497 (m), 1455 (m), 1351 (m), 1308 (m), 1295 (m), 1236 (s), 1268 (m), 1134 (s), 1061 (s), 1013 (s), 970 (w), 940 (m), 911 (m), 884 (m), 829 (w), 818 (w), 800 (w), 788 (w), 749 (m), 735 (m), 720 (m), 700 (s), 677 (w), 634 (w) cm^{-1}. ^{1}H NMR (200 MHz, CDCl$_3$, Me$_4$Si): δ = 7.42–7.28 (m, 5 H, phenyl), 4.58 (s, 1 H, 2-H), 4.51 (br. d, $^{3}J_{H,H}$ = 11.4 Hz, 1 H, 6-H), 4.14 (br. s, 1 H, 3-H), 4.04–3.96 (m, 1 H, 1 H of CH$_2$ of OEt), 3.69–3.60 (m, 1 H, 1 H of CH$_2$ of OEt), 2.68–2.52 (m, 1 H, 4-H), 2.52 (br. s, 1 H, OH), 2.32–2.13 (m, 1 H, 5-H), 1.89 (br. d, $^{2}J_{H,H}$ = 13.2 Hz, 1 H, 5-H), 1.25 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH$_3$ of OEt) ppm. ^{13}C NMR (50 MHz, CDCl$_3$): δ = 140.4 (C), 128.5 (2 CH), 128.0 (CH), 125.9 (2 CH), 100.7 (CH), 76.0 (CH), 64.6 (CH$_2$), 64.2 (CH), 41.9 (t, *J* = 21.1 Hz, CH), 26.3 (CH$_2$), 15.0 (CH$_3$) ppm. MS (EI): *m/z* (%) = 439 (2), 395 (18), 366 (73), 348 (87), 335 (90), 317 (100), 287 (48), 272 (38), 116 (39), 105 (92), 89 (46), 59 (30). HRMS: *m/z* calcd. for $C_{15}H_{12}O_2F_9$ ([M – OEt]$^+$) 395.0694; found 395.0706.

(2R*,3S*,4R*,6S*)-8d-I: IR (film): $\tilde{\nu}_{max}$ = 3444 (m), 3066 (w), 3034 (w), 2979 (m), 2929 (m), 1497 (w), 1455 (m), 1377 (m), 1354 (m), 1322 (m), 1295 (m), 1234 (s), 1166 (m), 1134 (s), 1068 (m), 1049 (m), 1029 (m), 980 (w), 961 (w), 906 (w), 848 (w), 816 (w), 795 (w), 748 (m), 735 (w), 721 (m), 699 (m) cm^{-1}. ^{1}H NMR (200 MHz, CDCl$_3$, Me$_4$Si): δ = 7.40–7.29 (m, 5 H, phenyl), 5.01 (m, 1 H, 6-H), 4.83 (m, 1 H, 2-H), 4.06 (br. s, 1 H, 3-H), 3.63–3.55 (m, 1 H, 1 H of CH$_2$ of OEt), 3.45–3.67 (m, 1 H, 1 H of CH$_2$ of OEt), 3.22–3.10 (m, 1 H, OH), 2.50–2.43 (m, 1 H, 4-H), 2.33–2.17 (m, 2 H, 5-H), 0.87 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH$_3$ of OEt) ppm. ^{13}C NMR (50 MHz, CDCl$_3$): δ = 165.3 (C), 128.4 (2 CH), 127.4 (CH), 126.1 (2 CH), 100.7 (CH), 71.0 (CH), 67.4 (CH), 64.2 (CH$_2$), 35.8 (CH), 24.7 (CH$_2$), 14.6 (CH$_3$) ppm. MS (EI): *m/z* (%) = 440 (2), 402 (12), 395 (8), 349 (22), 335 (36), 317 (23), 177 (14), 146 (47), 128 (49), 116 (93), 103 (95), 88 (100), 60 (94). HRMS: *m/z* calcd. for $C_{17}H_{17}O_3F_9$ [M$^+$] 440.1034; found 440.1036.

2-Ethoxy-4-(perfluorobutyl)-6-phenyltetrahydropyran-3-ol [(2R*,3R*/3S*,4R*/4S*,6R*)-8d-I]: The compound was prepared from 0.25 g (0.56 mmol) of (2R*,4R*/4S*,6R*)-**12d-I** with a 4R*/4S* ratio of 30:70. Solvent evaporation gave 0.21 g (84%) of (2R*,3R*/3S*,4R*/4S*,6R*)-**8d-I** as a yellowish liquid consisting of a mixture of two pairs of diastereomers. The isomeric composition was determined by ^{1}H NMR investigations of the product mixture before isolation of the major isomers started, using the integrals of the anomeric protons to determine the isomeric composition. The anomeric protons showed the following chemical shifts and relative intensities: 5.00 ppm, 78% (3S*,4R*); 4.94 ppm, 22% (3S*,4S*); no signals due to the (3R*,4R*) and (3R*,4S*) diastereomeric pairs were observed. Separation and purification were carried out by flash chromatography (hexane/ethyl acetate in a 90:10 ratio), and both diastereomeric pairs, with a *cis* relationship between the OH and EtO groups, were isolated pure.

(2R*,3S*,4R*,6R*)-8d-I: IR (film): $\tilde{\nu}_{max}$ = 3565 (m), 2388 (m), 3092 (w), 3067 (w), 3035 (w), 2979 (m), 2931 (m), 1498 (m), 1454 (m), 1403 (m), 1352 (m), 1236 (s), 1135 (s), 1057 (s), 1030 (w), 982 (w), 956 (w), 937 (m), 912 (w), 884 (w), 867 (w), 854 (w), 841 (w), 782 (w), 760 (m), 747 (m), 730 (m), 665 (w), 649 (w) cm^{-1}. ^{1}H NMR (200 MHz, CDCl$_3$, Me$_4$Si): δ = 7.42–7.29 (m, 5 H, phenyl), 5.00 (d, $^{3}J_{H,H}$ = 3.6 Hz, 1 H, 2-H), 4.83 (br. d, $^{3}J_{H,H}$ = 11.4 Hz, 1 H, 6-H), 3.99 (dt, $^{3}J_{H,H}$ = 3.6, $^{3}J_{H,H}$ = 10.8 Hz, 1 H, 3-H), 3.90–3.80 (m, 1 H, 1 H of CH$_2$ of OEt), 3.65–3.55 (m, 1 H, 1 H of CH$_2$ of OEt), 3.00–2.83 (m, 1 H, 4-H), 2.22 (d, $^{3}J_{H,H}$ = 11.4 Hz, 1 H, OH), 2.11 (m, 1 H, 5-H), 1.76 (m, 1 H, 5-H), 1.28 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH$_3$ of OEt) ppm. ^{13}C NMR (50 MHz, CDCl$_3$): δ = 140.3 (C), 128.6 (2 CH), 128.1 (CH), 126.1 (2 CH), 98.0 (CH), 69.4 (CH), 66.3 (CH), 63.8 (CH$_2$), 41.7 (t, *J* = 20.5 Hz, CH), 31.5 (CH$_2$), 15.0 (CH$_3$) ppm. MS (EI): *m/z* (%) = 440 (4), 421 (10), 393 (38), 375 (32), 365 (27), 347 (24), 161 (22), 133 (30), 104 (100), 91 (81), 73 (52), 59 (75). HRMS: *m/z* calcd. for $C_{17}H_{17}O_3F_9$ [M$^+$] 440.1034; found 440.1053.

(2R*,3S*,4S*,6R*)-8d-I: IR (film): $\tilde{\nu}_{max}$ = 3582 (m), 3444 (m), 3089 (w), 3064 (w), 3031 (w), 2928 (s), 2873 (m), 2856 (m), 1496 (m), 1453 (m), 1403 (m), 1375 (m), 1343 (m), 1235 (s), 1219 (m), 1185 (m), 1163 (m), 1135 (s), 1112 (m), 1050 (s), 1028 (s), 1003 (m), 944 (w), 910 (w), 893 (w), 845 (w), 798 (w), 756 (m), 699 (s), 636 (m) cm^{-1}. ^{1}H NMR (200 MHz, CDCl$_3$, Me$_4$Si): δ = 7.40–7.30 (m, 5 H, phenyl), 4.94 (d, $^{3}J_{H,H}$ = 3.6 Hz, 1 H, 2-H), 4.72 (dd, $^{3}J_{H,H}$ = 1.8, $^{3}J_{H,H}$ = 11.0 Hz, 1 H, 6-H), 3.90–3.83 (m, 1 H, 1 H of CH$_2$ of OEt), 3.80–3.71 (m, 1 H, 3-H), 3.59–3.51 (m, 1 H, 1 H of CH$_2$ of OEt), 2.67–2.52 (m, 1 H, 4-H), 2.33–2.18 (m, 3 H, 5-H and OH), 1.27 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH$_3$ of OEt) ppm. ^{13}C NMR (50 MHz, CDCl$_3$): δ = 141.6 (C), 128.4 (2 CH), 127.6 (CH), 126.1 (2 CH), 98.4 (CH), 70.3 (CH), 67.8 (CH), 63.3 (CH$_2$), 29.7 (CH), 28.0 (CH$_2$), 15.2 (CH$_3$) ppm. MS (EI): *m/z* (%) = 440 (2), 392 (3), 375 (3), 177 (12), 133 (42), 103 (34), 89 (100), 73 (78), 59 (93). HRMS: *m/z* calcd. for $C_{15}H_{12}O_2F_9$ ([M$^+$ – OEt]) 395.0694; found 395.0691.

2-Ethoxy-6,6-dimethyl-4-(perfluorobutyl)tetrahydropyran-3-ol [(2R*,3R*/3S*,4R*/4S*)-8e-I]: The compound was prepared from 0.39 g (1.00 mmol) of (2R*,4R*/4S*)-**12e-I** with a 4R*/4S* ratio of 15:85. Solvent evaporation gave 0.35 g (89%) of (2R*,3R*/3S*,4R*/4S*)-**8e-I** as a yellowish liquid consisting of a mixture of four pairs of diastereomers. The isomeric composition was determined by ^{1}H NMR investigations of the product mixture before isolation of the major isomers started, using the integrals of the anomeric protons to determine the isomeric composition. The anomeric protons showed the following chemical shifts and relative intensities: 4.80 ppm, 73% (3S*,4R*); 4.73 ppm, 11% (3R*,4R*); 4.57 ppm, 12% (3S*,4S*); 4.65 ppm, 4% (3R*,4S*). Separation and purification were carried out by flash chromatography (hexane/ethyl acetate in a 85:15 ratio), and the two diastereomeric pairs with a *trans* relationship between the perfluorobutyl and OEt groups were isolated pure.

(2R*,3S*,4R*)-8e-I: IR (film): $\tilde{\nu}_{max}$ = 3564 (m), 3495 (m), 2980 (s), 2935 (s), 2909 (s), 1454 (m), 1372 (m), 1351 (m), 1315 (m), 1215 (s), 1132 (s), 1070 (s), 983 (m), 942 (m), 885 (m), 808 (w), 798 (w), 736 (m), 703 (m) cm^{-1}. ^{1}H NMR (200 MHz, CDCl$_3$, Me$_4$Si): δ = 4.80 (d, $^{3}J_{H,H}$ = 4.0 Hz, 1 H, 2-H), 3.95–3.87 (m, 1 H, 1 H of CH$_2$ of OEt), 3.83 (dd, $^{3}J_{H,H}$ = 4.0, $^{3}J_{H,H}$ = 10.5 Hz, 1 H, 3-H), 3.55–3.48 (m, 1 H, 1 H of CH$_2$ of OEt), 2.91–2.78 (m, 1 H, 4-H), 2.32 (br. s, 1 H, OH), 1.85 (m, $^{2}J_{H,H}$ = 13.5 Hz, 1 H, 5-H), 1.62 (t, $^{2}J_{H,H}$ = 13.5 Hz, 1 H, 5-H), 1.38 (s, 3 H, 6-Me), 1.25 (s, 3 H, 6-Me), 1.24 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH$_3$ of OEt) ppm. ^{13}C NMR (50 MHz, CDCl$_3$): δ = 98.0 (CH), 71.8 (C), 67.0 (CH), 63.7 (CH$_2$), 38.5 (t, *J* = 20.5 Hz, CH), 34.7 (CH$_2$), 31.5 (CH$_3$), 26.4 (CH$_3$), 14.7 (CH$_3$) ppm. MS (EI): *m/z* (%) = 391 (1), 377 (53), 359 (58), 348 (72), 336 (71), 309 (55), 301 (80), 281 (84), 241 (84), 227 (72), 195 (56), 145 (58), 131 (77), 93 (94), 71 (100). HRMS: *m/z* calcd. for $C_{11}H_{12}O_2F_9$ ([M – OEt]$^+$) 347.0694; found 347.0688.

(2R*,3R*,4R*)-8e-I: IR (film): $\tilde{\nu}_{max}$ = 3423 (s), 2973 (s), 2924 (m), 1483 (m), 1376 (m), 1322 (m), 1234 (s), 1137 (s), 1073 (m), 1054 (m), 1029 (m), 976 (m), 937 (m), 885 (m), 851 (w), 800 (m) cm^{-1}. ^{1}H NMR (200 MHz, CDCl$_3$, Me$_4$Si): δ = 4.73 (d, $^{3}J_{H,H}$ = 1.9 Hz, 1 H, 2-H), 4.03 (s, 1 H, 3-H), 3.89–2.81 (m, 1 H, 1 H of CH$_2$ of OEt), 3.53–3.45 (m, 1 H, 1 H of CH$_2$ of OEt), 3.06–2.93 (m, 1 H, 4-H), 2.09 (t, $^{2}J_{H,H}$ = $^{3}J_{H,H}$ = 13.5 Hz, 1 H, 5-H), 1.83 (br. s, 1 H, OH), 1.62 (dd, $^{3}J_{H,H}$ = 2.7, $^{2}J_{H,H}$ = 13.5 Hz, 1 H, 5-H), 1.39 (s, 3 H, 6-Me), 1.31 (s, 3 H, 6-Me), 1.19 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH$_3$ of OEt) ppm. ^{13}C NMR (50 MHz, CDCl$_3$): δ = 100.0 (CH), 72.2

(C), 64.3 (CH), 63.2 (CH_2), 34.5 (t, *J* = 19.8 Hz, CH), 32.2 (CH_3), 29.1 (CH_2), 26.8 (CH_3), 14.7 (CH_3) ppm.

2-Ethoxy-4-(perfluorobutyl)-1-oxaspiro[5.5]undec-3-ol [(2R*,3R*/3S*,4R*/4S*)-8f-I]: The compound was prepared from 0.43 g (1.00 mmol) of (2R*,4R*/4S*)-**12f-I** with a 4R*/4S* ratio of 20:80. Solvent evaporation gave 0.38 g (88%) of (2R*,3R*/3S*,4R*/4S*)-**8f-I** as a yellowish liquid consisting of a mixture of three pairs of diastereomers. The isomeric composition was determined by ^{1}H NMR investigations of the product mixture before isolation of the major isomers started, using the integrals of the anomeric protons to determine the isomeric composition. The anomeric protons showed the following chemical shifts and relative intensities: 4.81 ppm, 80% (3S*,4R*); 4.61 ppm, 3% (3R*,4S*); 4.56 ppm, 17% (3S*,4S*); no signal due to the (3R*,4R*) isomer was observed. Separation and purification were carried out by flash chromatography (hexane/ethyl acetate in a 90:10 ratio), and the most abundant diastereomeric pair, with a *cis* relationship between the OH and OEt groups, was isolated pure.

(2R*,3S*,4R*)-8f-I: IR (film): $\tilde{\nu}_{max}$ = 3491 (m), 2936 (s), 2863 (m), 1484 (w), 1450 (m), 1404 (m), 1374 (m), 1352 (m), 1317 (m), 1293 (m), 1236 (s), 1134 (s), 1063 (s), 998 (m), 964 (m), 918 (m), 880 (m), 745 (m), 737 (m), 696 (m) cm^{-1}. ^{1}H NMR (200 MHz, $CDCl_3$, Me_4Si): δ = 4.81 (d, $^{3}J_{H,H}$ = 4.0 Hz, 1 H, 2-H), 4.01–3.93 (m, 1 H, 1 H of CH_2 of OEt), 3.84 (dd, $^{3}J_{H,H}$ = 4.0, $^{3}J_{H,H}$ = 10.3 Hz, 1 H, 3-H), 3.63–3.53 (m, 1 H, 1 H of CH_2 of OEt), 2.87–2.73 (m, 1 H, 4-H), 2.41 (br. s, 1 H, OH), 2.05–1.96 (m, 2 H, 5-H), 1.79–1.34 (m, 10 H, 5 CH_2 of cyclohexyl), 1.23 (t, $^{3}J_{H,H}$ = 7.0 Hz, 3 H, CH_3 of OEt) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 98.1 (CH), 73.2 (C), 67.3 (CH), 64.6 (CH_2), 40.1 (CH_2), 38.3 (t, *J* = 20.1 Hz, CH), 35.4 (CH_2), 32.7 (CH_2), 25.8 (CH_2), 22.5 (CH_2), 22.2 (CH_2), 14.7 (CH_3) ppm. MS (EI): *m/z* (%) = 432 (18) [M^+], 387 (8), 369 (10), 358 (15), 343 (22), 167 (46), 141 (72), 138 (91), 109 (85), 97 (95), 69 (100). HRMS: *m/z* calcd. for $C_{16}H_{21}O_3F_9$ [M^+] 432.1347; found 432.1351.

Supporting Information (see also the footnote on the first page of this article): ^{19}F NMR spectroscopic data.

Acknowledgments

Financial support (to L. K. S.) from the Research Council of Norway is highly appreciated. Recording of mass spectra by Dr. Dag Egeberg at Norwegian University of Environmental and Biological Sciences is highly appreciated. Institut für Organische Chemie, Universität Wien, Austria and Professor Udo H. Brinker are gratefully acknowledged for excellent working conditions during a recent sabbatical stay.

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[1] a) C. Zur, A. O. Miller, R. Miethchen, *Liq. Cryst.* **1998**, *24*, 695–699; b) J. G. Riess, M. P. Krafft, *Biomaterials* **1998**, *19*, 1529–1539; c) F. Ghomashchi, R. Loo, J. Balsinde, F. Bartoli, R. Apitz-Castro, J. D. Clark, *Biochim. Biophys. Acta* **1999**, *1420*, 45–56; d) M. Pabon, J. M. Corpart, *J. Fluorine Chem.* **2002**, *114*, 149–156; e) J. G. Riess, J. Greiner, *Carbohydr. Res.* **2000**, *327*, 147–168; f) J. G. Riess, *Chem. Rev.* **2001**, *101*, 2797–2919; g) F. Guittard, S. Geribaldi, *J. Fluorine Chem.* **2001**, *107*, 363–374; h) H. Sawada, *J. Fluorine Chem.* **2003**, *121*, 111–130; i) K. C. Lowe, *J. Fluorine Chem.* **2001**, *109*, 59–65; j) J. G. Riess, *J. Fluorine Chem.* **2002**, *114*, 119–126; k) K. C. Lowe, *J. Fluorine Chem.* **2002**, *118*, 19–26.

[2] a) I. P. Street, H.-K. Lin, F. Laliberte, F. Ghomashchi, Z. Wang, H. Perrier, N. M. Tremblay, Z. Huang, P. K. Weech, M. H. Gelb, *Biochemistry* **1993**, *32*, 5935–5940; b) L. A. Trimble, I. P. Street, H. Perrier, N. M. Tremblay, P. K. Weech, M. A. Bernstein, *Biochemistry* **1993**, *32*, 12560–12565; c) F. Guillod, J. Greiner, J. G. Riess, *Carbohydr. Res.* **1994**, *261*, 37–55; d) E. Mayot, C. Géradin-Charbonnier, C. Selve, *J. Fluorine Chem.* **2005**, *126*, 715–720; e) Y.-M. Wu, J. Deng, Y. Li, Q.-Y. Chen, *Synthesis* **2005**, 1314–1318; f) Z. Kaleta, O. Egyed, T. Soós, *Org. Biomol. Chem.* **2005**, *3*, 2228–2230; g) M. Houde, J. W. Martin, R. J. Letcher, K. R. Solomon, D. C. G. Muir, *Environ. Sci. Technol.* **2006**, *40*, 3463–3473; h) K. Müller, C. Faeh, F. Diederich, *Science* **2007**, *317*, 1881–1886 and references cited therein; i) C. Baskakis, V. Magrioti, N. Cotton, D. Stephens, V. Constantinou-Kokotou, E. A. Dennis, G. Kokotos, *J. Med. Chem.* **2008**, *51*, 8027–8037.

[3] N. O. Brace, *J. Fluorine Chem.* **1999**, *96*, 101–127.

[4] a) A. O. Miller, D. Peters, C. Zur, M. Frank, R. Miethchen, *J. Fluorine Chem.* **1997**, *82*, 33–38; b) C. Zur, A. O. Miller, R. Miethchen, *J. Fluorine Chem.* **1998**, *90*, 67–76; c) C. Zur, R. Miethchen, *Eur. J. Org. Chem.* **1998**, 531–539; d) D. Peters, C. Zur, R. Miethchen, *Synthesis* **1998**, 1033–1038; e) R. Miethchen, M. Hein, H. Reinke, *Eur. J. Org. Chem.* **1998**, 919–923; f) M. Mastihubová, P. Biely, *Carbohydr. Res.* **2004**, *339*, 2101–2110; g) V. Cirkva, R. Polák, O. Paleta, K. Kefurt, J. Moravcová, M. Kodicek, S. Forman, *Carbohydr. Res.* **2004**, *339*, 2177–2185; h) F. Poulain, A.-L. Serre, J. Lalot, E. Leclerc, J.-C. Quirion, *J. Org. Chem.* **2008**, *73*, 2435–2438.

[5] a) Y. Takeyama, Y. Ichinose, K. Oshima, K. Utimoto, *Tetrahedron Lett.* **1989**, *30*, 3159–3162; b) W. Huang, L. Lu, Y.-F. Zhang, *Chin. J. Chem.* **1990**, 350–354; c) W. Huang, Y. Xie, *Chin. J. Chem.* **1990**, 362–369; d) W. Huang, Y. Xie, *Chin. J. Chem.* **1991**, 351–359; e) W. Huang, *J. Fluorine Chem.* **1992**, *58*, 1–8; f) P. Cao, J. X. Duan, Q. Y. Chen, *J. Chem. Soc., Chem. Commun.* **1994**, 737–738; g) F.-H. Wu, B.-N. Huang, L. Lu, W.-Y. Huang, *J. Fluorine Chem.* **1996**, *80*, 91–94; h) A.-R. Li, Q.-Y. Chen, *J. Fluorine Chem.* **1997**, *82*, 151–155; i) J.-T. Liu, W.-Y. Huang, *J. Fluorine Chem.* **1999**, *95*, 131–133.

[6] K. Miura, Y. Takeyama, K. Oshima, K. Utimoto, *Bull. Chem. Soc. Jpn.* **1991**, *64*, 1542–1553.

[7] W. Zhu, Z. Li, *J. Chem. Soc. Perkin Trans. 1* **2000**, 1105–1108.

[8] L. K. Sydnes, B. Holmelid, O. H. Kvernenes, S. Valdersnes, M. Hodne, K. Boman, *ARKIVOC* **2008**, *14*, 242–268.

[9] a) L. K. Sydnes, E. Bakstad in *Advances in Strain in Organic Chemistry* (Ed.: B. Halton), JAI Press, Greenwich CN, **1996**, vol. 5, pp. 85–119; b) E. Bakstad, L. K. Sydnes, *Acta Chem. Scand.* **1998**, *52*, 1029–1033; c) L. K. Sydnes, *Eur. J. Org. Chem.* **2000**, 3511–3518; d) L. K. Sydnes, O. H. Kvernenes, S. Valdersnes, *Pure Appl. Chem.* **2005**, *77*, 119–130; e) O. H. Kvernenes, L. K. Sydnes, *Org. Synth.* **2006**, *83*, 184–192; f) L. K. Sydnes, B. Holmelid, O. H. Kvernenes, M. Sandberg, M. Hodne, E. Bakstad, *Tetrahedron* **2007**, *63*, 4144–4148.

[10] a) E. J. Corey, R. K. Bakshi, S. Shibata, *J. Am. Chem. Soc.* **1987**, *109*, 5551–5553; b) E. J. Corey, R. K. Bakshi, S. Shibata, *J. Am. Chem. Soc.* **1987**, *109*, 7925–7926; c) E. J. Corey, S. Shibata, R. K. Bakshi, *J. Org. Chem.* **1988**, *53*, 2861–2863; d) E. J. Corey, *Pure Appl. Chem.* **1990**, *62*, 1209–1216; e) E. J. Corey, C. J. Helal, *Angew. Chem. Int. Ed.* **1998**, *37*, 1986–2012.

[11] W. Huang, Y. Xie, L. Lu, *Chin. J. Chem.* **1991**, *9*, 167–173.

[12] a) R. M. Beesley, C. K. Ingold, J. F. Thorpe, *J. Chem. Soc.* **1915**, *107*, 1080–1106; b) C. K. Ingold, *J. Chem. Soc. Trans.* **1921**, *119*, 305–329; c) C. K. Ingold, *J. Chem. Soc. Trans.* **1921**, *119*, 951–970; d) C. K. Ingold, S. Sako, J. F. Thorpe, *J. Chem. Soc. Trans.* **1922**, *121*, 1177–1198; e) N. L. Allinger, V. Zalkow, *J. Org. Chem.* **1960**, *25*, 701–704; f) S. W. Smith, M. S. Newman, *J. Am. Chem. Soc.* **1968**, *90*, 1253–1257; g) G. Borgen, J. Dale, *Acta Chem. Scand.* **1972**, *26*, 952–960; h) J. Dale, *Acta Chem. Scand.* **1973**, *27*, 1149–1158; i) S. L. Björnstad, G. Borgen, J. Dale, G. Gaupset, *Acta Chem. Scand., Ser. B* **1975**, *B29*, 320–324; j) J. Kaneti, A. J. Kirby, A. H. Koedjikov, I. G. Pojarlieff, *Org. Biomol. Chem.* **2004**, *2*, 1098–1103.

Received: June 20, 2009