Synthesis of a Butyrolactone Precursor of an Algae Nonaether from an Enantiopure Glycol Obtained by Hoppe's Chemistry

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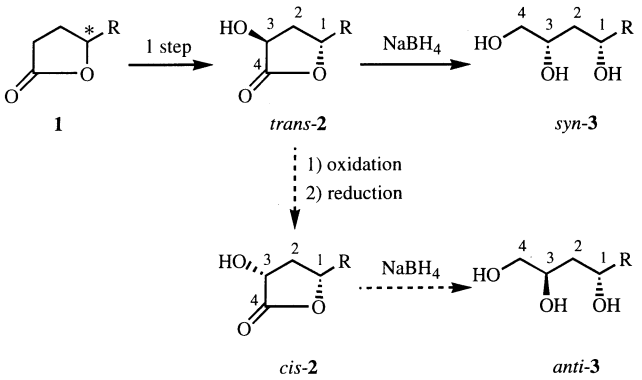
Homoallyl carbamate **20**, (–)-sparteine, and *s*BuLi gave a lithium derivative which was formylated with DMF giving the crude aldehydocarbamate **19**. With lithium aluminum hydride in refluxing THF, this compound provided diol **22** in 90% overall yield and with 96% *ee*. This material was carried on to the γ-lactone monoethers **13** (benzyl ether) or **14** (trityl ether). These compounds should be precursors for synthesizing the naturally occurring nonaether **7**.

The dia- and entioselective synthesis of 1,3,5,7,...-polyols has attracted much attention in the last decade.[1] Among the many strategies which have been developed to this end, there are two using γ-lactones as key intermediates. The first lactone strategy was devised by Hanessian et al. (Scheme 1),[2] the second − conceptionally completely different − by ourselves (Scheme 2).[3][4][5] Hanessian's lactones **1** are carried on to 1,3-diols **3** such that they contribute all four carbon ring atoms to the target structure. Our lactones **4** are deprived of one center through an oxidative degradation before they contribute three carbon ring atoms to 1,3-diols of structure **6**.

In both lactone strategies, diastereocontrol is exerted in a lactone-functionalizing step. The enolate of Hanessian's starting lactone **1** is hydroxylated with $MoO_5 \cdot$pyridine *trans*-selectively (→ hydroxylactone **2**; Scheme 1). The newly formed C−O bond and the already present C−O bond are accordingly oriented *syn* in the subsequently obtained triol *syn*-**3**. The C^4-C^3-O moiety of this triol was incorporated into a new γ-lactone by sequential activation as an epoxide, C_2 elongation, and OH-group protection. Repeting the enolate hydroxylation and lactone reduction steps with the new lactone makes Hanessian's *syn*-1,3-diol synthesis reiterative. In the described case one reached a 1-(hydroxymethyl) substituted *syn*,*syn*-1,3,5-*triol*. The strategy of Scheme 1 was not extended to synthesizing a 1,3-diol *anti*-**3** (except as part of one *syn*,*anti*-1,3,5-triol[2]) let alone a higher all-*anti*-1,3,5,...-polyol. However, such an extension appears easily possible. One would simply have to oxidize α-hydroxylactones *trans*-**2** to a α-keto lactones and reduce the latters with a hydride donor from the least hindered face. The resulting hydroxylactones would be of type *cis*-**2**. They should furnish 1,3-diols *anti*-**3** upon further reduction − perhaps still in the same operation.

Scheme 1. Hanessian's γ-butyrolactone→*syn*-1,3-diol conversions (full arrows)[2] and an untried yet plausible bifurcation to an isomeric *anti*-1,3-diol (dashed arrows)



The Priepke/Menges lactone strategy has made 1,3-diols **6** of *choosable syn* or *anti* configuration accessible (Scheme 2). The stereo-determining step is either an overall *cis*-selective (→ alkyllactone *cis*-**5**; Scheme 1) or a genuine *trans*-selective (→ alkyllactone *trans*-**5**) alkylation of the enolate of starting lactones **4**.[2][3][5c] Such *cis*-alkylations were realized either in a single operation consisting of a *trans*-alkylation, a renewed deprotonation, and a reprotonation or in two separate operations, i. e. by an aldol condensation followed by a catalytic hydrogenation.[2][5a][5b] Subsequently, the C^3-C^4 bond of the obtained lactones *cis*- or *trans*-**5** is degraded − via a Criegee rearrangement − with complete retention of configuration to the C^3-OH bond of the 1,3-diols *syn*- or *anti*-**6**, respectively. Our strategy is extendable to higher polyols: not reiteratively, but so far in form of several *bis*(γ-lactone)→1,3,7,9-tetraol conversions.[3][5c] We wish to apply it now to an again more complex poylol in form of a *tris*(γ-lactone)→1,3,7,9,13,15-hexaol conversion. As a testing case, we chose the project outlined in Scheme 3. It aims at synthesizing the nonaether **7**. It stems − as well as analogous penta-, hexa-, octa-, and decaethers − from the blue-green algae *Tolypothrix conglutinata*, *Scy-*

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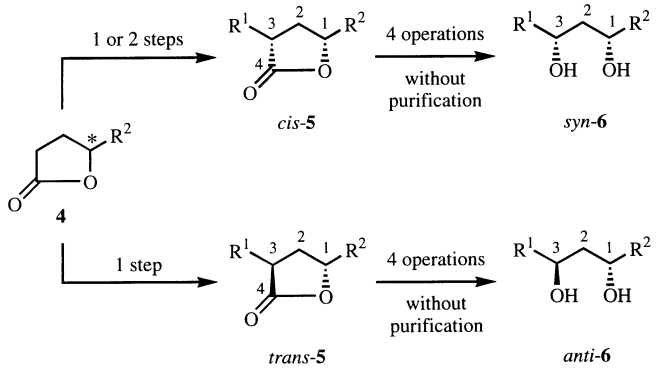
tonema mirabile, and *Scytonema burmanicum*.[6] Several total syntheses of compound **7** and its congeners have been published.[7]

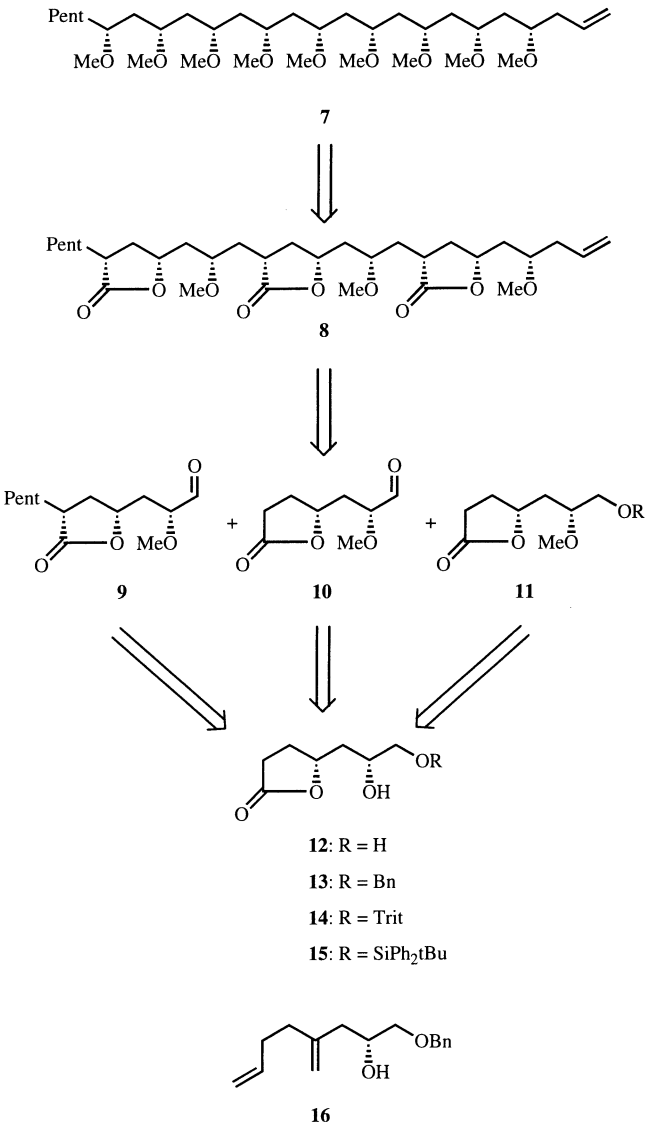
Scheme 2. Priepke's and Menges' γ-butyrolactone→1,3-diol conversions[3]



A triple oxidative γ-butyrolactone → 1,3-diol degradation of trislactone **8** shall become the key step of our approach to **7**. This trislactone shall be assembled through linking *cis*-selectively the aldehydolactone **9**, a suitably protected synthetic equivalent of the aldehydolactone **10**, and lactone **11**. These three lactones possess an identical core. Hence, they shall be derived from one and the same progenitor lactone **12**. Therein, the primary OH group must be protected and the secondary OH group methylated.

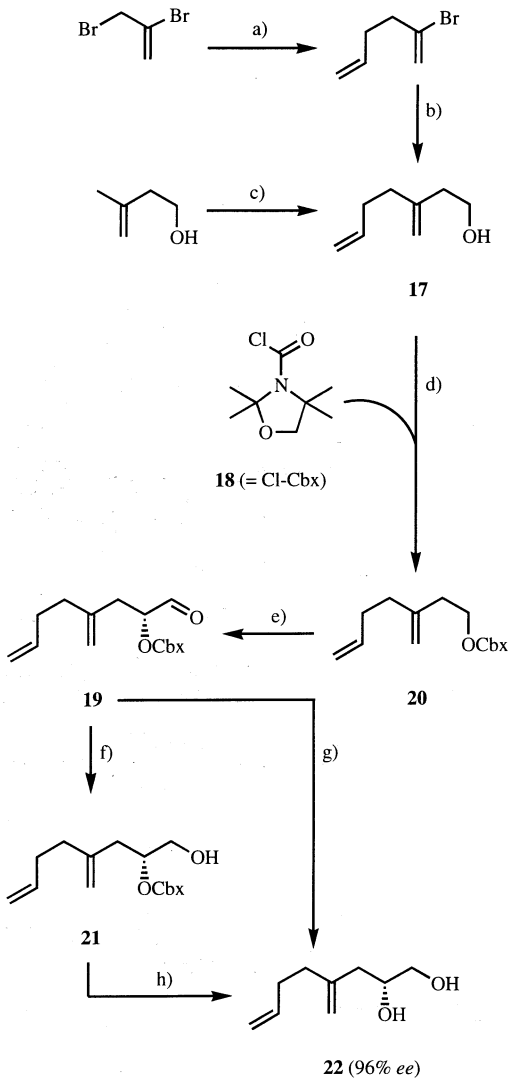
Striving for such a derivative of building block **12** already in another context we prepared the *tert*-butyldiphenylsilyl ether **15** earlier.[8] However, a 1,2-silyl-shift competed therein with the subsequently required *O*-methylation. In order to avoid such a rearrangement in approaching nonaether **7**, we desired the benzyl ether **13** or the trityl ether **14** as a modified starting material. Also, the synthesis of *tert*-butyldiphenylsilyl ether **15** was associated with a stereoselectivity problem: Originating from commercially available *S*-glycidol of ca. 90% *ee* **15** possessed ca. 90% *ee*, too. Clearly, a *similarly* derived benzyl ether **13** or trityl ether **14** would be inconvenient if not useless because of its then also only 90% *ee* for proceeding to a trislactone **8**: As soon as one would *combine* two such lactones, an unwanted diastereomer would form besides each wanted product.[9] Hence, we abandoned for good *S*-glycidol of 90% *ee* as a starting material and started from *trans*-HO−CH_2−CH=CH−$SiMe_3$[10] a slightly modified sequence towards **13**. We epoxidized by the Katsuki-Sharpless procedure (97%),[11] benzylated the resulting epoxyalcohol (NaH, BnBr; 71%), and desilylated the obtained product with Bu_4NF. *O*-Benzyl-*S*-glycidol was isolated in 93% yield with 99% *ee*. The Grignard reagent from 2-bromo-1,5-hexadiene[12] ring-opened this epoxide in the presence of 16 mol-% CuI regioselectively at the CH_2 group giving the benzyl ether **16** (66%). Ozonolyzis provided a keto ester of the structure O_{prim}-benzyl-**27** (30−57%). However, it contained O_{prim}-benz*o*yl-**27** (6−40%) which we couldn't separate. Literature precedence[13] suggests that such a benzyl ether → benzoate oxidation may be unavoidable during ozonolyses of C=C bonds. Considering this circumstance and the length of this approach we quit it. Instead, we developed the strategy detailed in Schemes 4 and 5.

Scheme 3. Retrosynthetic analysis of the nonaether from *Tolypothrix conglutinata*



2-Bromo-1,5-hexadiene was synthesized from 2,3-dibromopropene as described (Scheme 4).[8a][12] Conversion to the Grignard reagent, addition of 10 mol-% CuI, and ring-opening of ethylene oxide rendered the dienol **17** in 70% yield. Since 2,3-dibromopropene is prepared from allyl bromide in two steps,[14] this synthesis of **17** is somewhat lengthy. A one-step alternative starts from commercially available 3-methylene-1-butanol (Scheme 4). According to a literature report,[15] this alcohol is metalable with excess *n*BuLi/TMEDA[16] and can then be functionalized by *substituted* allyl bromides. Under these conditions, however, we observed only 50% consumption of the butanol. The same was true working with the Lochmann/Schlosser base.[17] 80% of the 3-methylene-1-butanol reacted, however, when we generated its allyl potassium derivative through successive treatments with KH and *n*BuLi. Unfortunately, the resulting dienol **17** was inseparable from still 20% of unre-

Scheme 4. a) $H_2C{=}CH\text{-}CH_2MgBr$ (2.0 equiv.), THF, reflux, 2 h; 76%.[8a] − b) Mg (1.15 equiv.), THF, 40°C, 2 h; → −30°C; CuI (0.1 equiv.), 30 min; ethylene oxide (1.0 equiv.), 30 min: $BF_3{\cdot}OEt_2$ (0.3 equiv.); → room temp., overnight; 70%. − c) KH (1.2 equiv.), hexane, 0°C → room temp., 1.5 h; *n*BuLi (1.0 equiv.), hexane, 0°C → room temp., 4.5 h; $H_2C{=}CH\text{-}CH_2Br$ (1.05 equiv.), hexane, room temp., 8 h; 28−33%. − d) NaH (1.3 equiv), THF, room temp., 30 min; addition of **18** (1.1 equiv.), room temp., 3 d; 79%. − e) *s*BuLi (2.4 equiv.), (−)-sparteine (1.2 equiv.), Et_2O, −78°C, 2 h; DMF (6 equiv.), −78°C → room temp. − f) $LiAlH_4$ (≥ 1.0-fold molar quantity), THF, 0°C, 15 min; 78% from **20**. − g) $LiAlH_4$ (≥ 2.0-fold molar quantity), THF, 0°C → reflux, 3 h; 73% from **20**. − h) $LiAlH_4$ (2.0-fold molar quantity), THF, reflux, 8 h; 90%



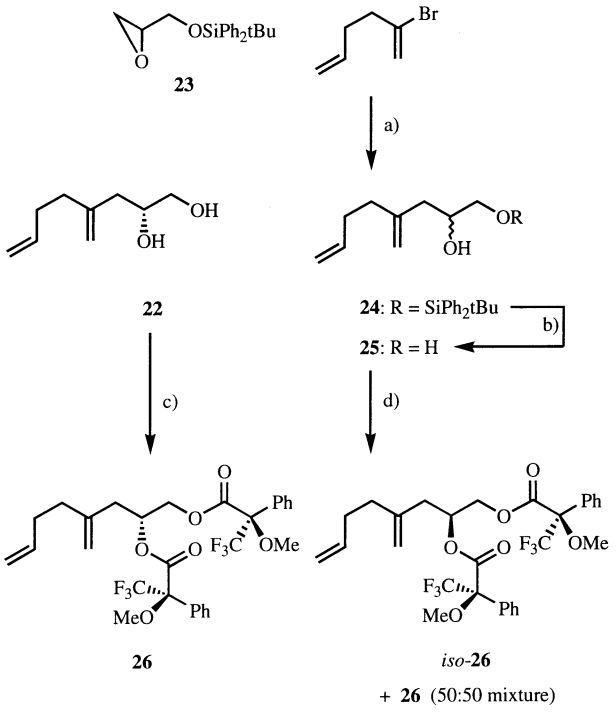
acted starting alcohol by flash chromatography on silica gel.[18] Distillation of the mixture effected a clean separation. However, we suffered considerable yield losses through decomposition. Still, the achievable 28−33% yield sufficed to produce decagram quantities of **17** in a single experiment.

Following a general procedure from the literature,[19] the sodium salt of dienol **17** was now carbamoylated with carbamoyl chloride **18** to 79% of compound **20**. We planned to hydroxymethylate this substance by one of Hoppe's enantioselective α-functionalizations of (−)-sparteine-modified *O*-alkylcarbamates.[20] Yet, this hydroxymethylation turned out to be more difficult than expected. Lithio-**20** didn't react at all with paraformaldehyde or with a Yamamoto-type Al(III) complex of formaldehyde.[21] Monomeric formaldehyde[22] was a viable reaction partner delivering, however, only 18% of the desired product. We changed thereupon the oxidation state of the electrophile with which we tried to scavenge sparteine-modified lithio-**20**. Neither methyl chloroformate nor diethyl carbonate nor MEM-chloride yielded the respective product, though. Only when we used DMF as the C_1 component we met success.[23] The obtained aldehyde **19** was not purified − to avoid racemization − but treated almost instantaneously with an equimolar amount of $LiAlH_4$ at 0°C in THF. Work-up after 15 min furnished the long-sought hydroxycarbamate **21** in 70% yield. Still, it first appeared as if we had arrived at a dead end with this compound. The usual removal of Hoppe's Cby group occurs through successive hydrolyses under strongly acidic and thereafter basic conditions.[20] However, after treating hydroxycarbamate **21** with $MeSO_3H$ TLC indicated already 100% decomposition. Presumably, the diene moiety of our carbamate had not stood up to these conditions. Fortunately, we got rid of the carbamate group through a reductive cleavage with $LiAlH_4$. This method has been described in the literature at least two times.[24] Accordingly, hydroxycarbamate **21** in THF solution was heated for several hours at reflux temperature in the presence of the twofold molar amout of the reductant. After quenching with methanol and HCl and flash chromatography we isolated the decarbamoylated compound **22** in 90% yield. It was possible to combine the aldehyde **19** → alcohol **21** and carbamate **21** → alcohol **22** reductions in a single operation: The crude formylation product **19** gave the dienediol **22** in a refluxing THF/$LiAlH_4$ mixture directly in 73% yield.

The optical purity of dienediol **22** was determined after condensation with (−)-Mosher's chloride[25] to diester **26** (Scheme 5). In addition, we prepared a 50:50 mixture of the same diester **26** and the diastereomeric diester *iso*-**26** from *racemic* **22** (≡ compound **25** of Scheme 5) and the same Mosher chloride. The synthesis of racemic **22** was straightforward in two steps (85%[26] and 77% yield, respectively) from the silylated glycidol **23**[27] and 2-bromo-1,5-hexadiene.[12] A 470 MHz ^{19}F-NMR spectrum of the 50:50 mixture of diesters **26** and *iso*-**26** showed for the constitutionally heterotopic CF_3 groups of each diastereomer two separate singlets. In the 470 MHz ^{19}F-NMR spectrum of the crude Mosher diester **26** obtained from our optically active dienediol **22** the integrals over the signals of **26** vs. *iso*-**26** showed that **22** possessed 96% *ee*. Seen this value, it should be emphasized that Hoppe's chemistry could be well suited for synthesizing enantiopure terminal glycols in general.

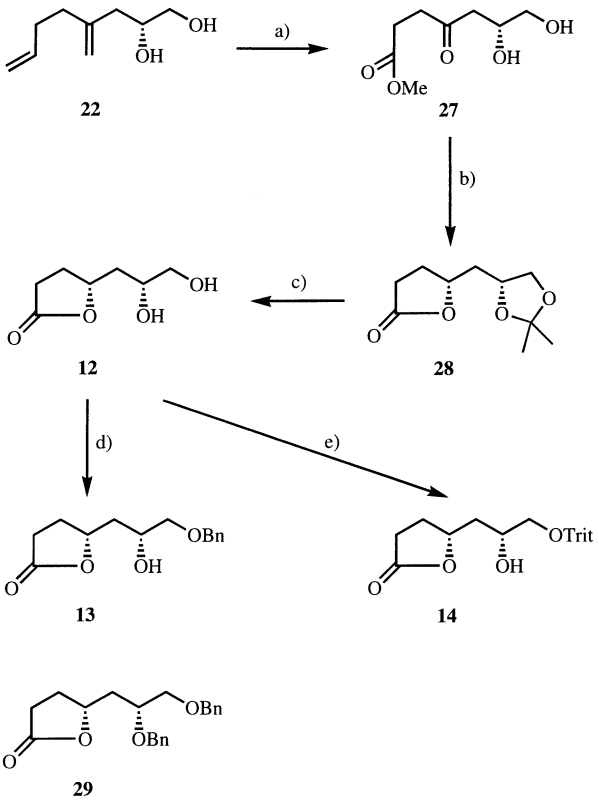
Scheme 6 shows how we processed the dienediol **22** for reaching the desired γ-butyrolactone core structure **12** as well as the protected derivatives **13** and **14** thereof. Priepke's variation[3a][8a] of the ozonolysis protocol from Schreiber's laboratory[28] allowed to cleave both C=C bonds of the di-

Scheme 5. a) Mg (1.6 equiv.), THF, 40°C, 30 min; CuI (0.14 equiv.), −30°C, addition of **23**, room temp., 8 h; 85%. − b) nBu$_4$NF (1.1 equiv.), THF, room temp., 4 h; 77%. − c) (*R*)-(−)-Mosher chloride (2.5 equiv.), DMAP (3.5 equiv.), THF, 1 h. − d) (*R*)-(−)-Mosher chloride (2.5 equiv.), DMAP (3.5 equiv.) THF, 1 h



enediol concomitantly. One gave a ketone, the other a methoxycxarbonyl group after refluxing the putative peroxoacetate intermediate in THF for 1.5 h. The keto ester **27** resulted in 78% yield. This compound contains a β-hydroxyketone moiety. The *syn*-reduction of β-hydroxyketones according to Narasaka et al.[29] through treatment of the derived β-(dialkylborinyloxy)ketone with $NaBH_4$ has become a stereochemically highly reliable reaction. The same stereochemistry was expected in the case of our "β-hydroxyketone" **27** which represents in truth a β,γ-dihydroxyketone. This is because Ticozzi and Zanarotti[30] effected a *completely syn*-selective reduction of (β,γ-dihydroxypropyl)-phenylketone under Narasaka's conditions. The only difference of their modus procedendi compared to the standard procedure[29] was that they transesterified the substrate with *two* equivalents of $Et_2B(OMe)$ − in order to protect *both* OH groups. Completely analogously, we treated the β,γ-dihydroxyketone **27** also first with two equivalents of $Et_2B(OMe)$ and thereafter with $NaBH_4$. We obtained the desired trihydroxy ester as a single diastereomer. In order to detach it from residual boron and to lower the polarity of the molecule for easier chromatography on silica gel, we added trifluoroacetic acid to the crude ester. This carried it on to the dihydroxylactone **12**. This compound was still too polar for complete extraction − continuous or discontinuous − from the aqueous into the organic phase. Therefore, the dihydroxyketone **12** was transacetalized with dimethoxypropane in the same vessel in which it had been formed. Thus we obtained the acetonide-protected lactone **28** in 63% yield relative to the ozonolysis product **27**. By cleaving the acetonide group off compound **27** with HCl in MeOH we got back a chemically and stereochemically *pure* dihydroxyketone **12** in 84% yield.

Scheme 6. a) O_3, MeOH, −78°C; O_2, → room temp.; *p*TsOH (cat.), 30 min; $NaHCO_3$; NEt_3 (2 equiv.), Ac_2O (1.1 equiv.), THF, 0°C → reflux, 1.5 h; 78%. − b) $Et_2B(OMe)$ (2.1 equiv.) in THF/MeOH (4:1), −78°C, 1 h; $NaBH_4$ (0.8 equiv.) THF/MeOH (4:1), −78°C, 3 h; CF_3COOH (3 equiv.), −78°C → room temp.; 2,2-dimethoxypropane (10 equiv.), CSA (cat.), acetone, room temp., 1 h; 63%. − c) HCl aq. (cat.), MeOH, room temp., 1 h, 84%. − d) Bu_2SnO (3.3 equiv.), nBu$_4$NBr (1.4 equiv.), MeCN, reflux, 10 h; BnBr (2.7 equiv.), MeCN, reflux, 2 d; 72%. − e) TritCl (1.5 equiv.), NEt_3 (1.6 equiv.), THF, room temp., 3 d; 83%



Finally, Scheme 6 shows how the two mono-protected derivatives **13** and **14** of dihydroxylactone **12** were finished. The monobenzyl ether **13** of dihydroxylactone **12** resisted attempted syntheses a long time. Following various benzylation protocols of the literature − in basic,[31] Lewis acidic,[32] or neutral media[33] − we observed neither the desired monoether **13** nor at least the undesired dibenzyl ether **29**.[34] After tedious optimization, we found an access through in-situ stannylation of the glycol moiety of dihydroxylactone **12** and subsequent treatment with benzyl bromide.[35] Benzyl ether **13** resulted in 72% yield. *It is the first possible key building block for synthesizing the nonaether* **7** *by the route conceived in Scheme 3*. The alternative key building block **14** for synthesizing compound **7** was available from dihydroxylactone **12** by a standard mono tritylation[36] in 83% yield.

Our syntheses of lactones **13** and **14** are satisfyingly short (7 steps from 3-methylene-1-butanol). The low yield of the

first step (→ 28−33% **17**) leaves them not high-yielding enough (6 and 7% overall yield, respectively), however. Ongoing optimization studies will hopefully resolve this problem and allow to proceed subsequently towards the target structure **7**.

We thank the *Fonds der Chemischen Industrie* for supporting this project and *Brigitte Worbs* for skilled technical assistance.

Experimental Section

All reactions were performed in oven-dried (100°C) glassware under N_2. THF was freshly distilled from K, CH_2Cl_2 from CaH_2. Products were purified by flash chromatography[18] on Merck silica gel 60 (eluents given in brackets). Yields refer to analytically pure samples. Isomer ratios were derived from suitable ^{1}H-NMR integrals. − ^{1}H NMR tetramethylsilane (δ = 0.00), $CHCl_3$ (δ = 7.26), C_6HD_5 (δ = 7.16) or CHD_2OD (δ = 3.30) as internal standard in the indicated solvent, in $CDCl_3$, C_6D_6 or CD_3OD, respectively; integrals in accord with assignments; coupling constants in Hz] and ^{13}C NMR [$CDCl_3$ (δ = 77.00) as internal standard in $CDCl_3$ or in $CDCl_3$/CD_3OD; always APT spectra with peak orientations in accord with assignments]: Bruker AMX 300 and Varian VXR 500S. The assignments of ^{1}H- and ^{13}C-NMR resonances refer to the IUPAC nomenclature, primed numbers to the side-chain (s in the order of their appearance in the IUPAC name). − Combustion analyses: M. Beller, Institute of Organic Chemistry, University of Göttingen. − Mass spectra: Dr. G. Remberg, Institute of Organic Chemistry, University of Göttingen. − IR spectra: Perkin-Elmer 1600 Series FTIR as solution in a NaCl cuvette. − Optical rotations: Perkin-Elmer polarimeter 241 at 589 nm; rotational values are the average of 4 measurements of α in a given solution of the respective sample.

(2′R,5R)-5-(2,3-Dihydroxypropyl)-4,5-dihydro-2(3H)-furanone (**12**): Acetonide **28** (82 mg, 0.41 mmol) in CH_2Cl_2 (1 ml) and MeOH (1 ml) was treated with one drop of HCl (2 M) and stirred overnight at room temp. Evaporation led to the title compound (55 mg, 84%). − $[\alpha]_D^{23}$ = −11.1 (*c* = 0.95, MeOH). − ^{1}H NMR (500 MHz, $CDCl_3$/CD_3OD)*: δ = AB signal (δ_A = 1.84, δ_B = 1.96, J_{AB} = 14.6, in addition split by $J_{A,5}$ = 4.8, $J_{A,2'}$ = 4.2, $J_{B,2'}$ = 8.1, $J_{B,5}$ = 6.3, 1′-H_2), identification of the B part splittings somewhat speculative due to overlap with 1.91−1.98 (m, 4-H^1), 2.41 (dddd, $J_{4\text{-H}(2),4\text{-H}(1)}$ = 12.7, $J_{4\text{-H}(2),5}$ = 7.3, $J_{4\text{-H}(2),3\text{-H}(1)}$ = 6.4, $J_{4\text{-H}(2),3\text{-H}(2)}$ = 5.8, 4-H^2), 2.54−2.58 (m, 3-H_2), AB signal (δ_A = 3.57, δ_B = 3.70, J_{AB} = 11.0, in addition split by $J_{A,2'}$ = 6.6, $J_{B,2'}$ = 3.4, 3′-H_2), 3.96 (m_c, presumably interpretable as dddd, $J_{2',1'\text{-H(B)}}$ = 7.7, $J_{2',3'\text{-H(A)}}$ = 6.7, $J_{2',1'\text{-H(A)}} \approx J_{2',3'\text{-H(B)}}$ = 3.9, 2′-H), 4.72 (dddd, $J_{5,4\text{-H(A)}} = J_{5,4\text{-H(B)}} = 8$.2, $J_{5,1'\text{-H(B)}}$ = 6.4, $J_{5,1'\text{-H(A)}}$ = 4.8, 5-H); OH resonance undetectable because of H/D exchange with the solvent; *assignments in analogy to corresponding signals of acetonide **28**. − ^{13}C NMR (126 MHz, $CDCl_3$/CD_3OD): δ = 27.87 and 28.39 (C-3, C-4), 38.26 (C-1′), 65.47 (C-3′), 68.92 (C-2′), 79.27 (C-5), 178.41 (C-2). − IR (CH_3OH): $\tilde{\nu}$ = 3385 cm^{-1}, 2940, 1765, 1420, 1355, 1190, 1065, 1015, 920, 805. − $C_7H_{12}O_4$ (160.2): calcd. C 52.49, H 7.55; found C 52.38, H 7.59.

(5R)-5-{(2R)-3-[(Benzyloxy)-2-hydroxypropyl]}-4,5-dihydro-2(3H)-furanone (**13**): Dihydroxylactone **12** (211 mg, 1.32 mmol), Bu_2SnO (1.09 g, 4.36 mmol, 3.3 equiv.), and nBu_4NBr (586 mg, 1.82 mmol, 1.4 equiv.) in MeCN solution (15 ml) were refluxed for 10 h in a Dean-Stark apparatus filled with 4 Å molecular sieves. Benzyl bromide (0.43 ml, 620 mg, 3.6 mmol, 2.7 equiv.) was added and refluxing continued for 2 h. The reaction was quenched by adding satd. aqueous $NaHCO_3$ solution and *t*BuOMe (20 ml). The aqueous layer was extracted (*t*BuOMe, 3 × 10 ml) and the resulting solution dried ($MgSO_4$) and concentrated in vacuo. Flash chromatography (3.0 cm, petroleum ether/*t*BuOMe, 1:5 → pure *t*BuOMe) yielded benzyl ether **13** (237 mg, 72%). − $[\alpha]_D^{25}$ = −19.9 (*c* = 1.33, CH_2Cl_2). − ^{1}H NMR (500 MHz, $CDCl_3$): δ = AB signal (δ_A = 1.80, δ_B = 1.98, J_{AB} = 14.4, in addition split by $J_{A,5}$ = 5.9, $J_{A,2'}$ = 4.3, $J_{B,2'}$ = 7−8, $J_{B,5}$ = 7.2, 1′-H_2), δ = 1.89−1.97 [m, presumably interpretable as A part of AB signal centered at δ = 1.94, (J_{AB} = 12.6, $J_{A,3\text{-H}(1)} = J_{A,3\text{-H}(2)}$ = 9.6, $J_{A,5}$ = 8.5, 4-H^A)], B part of AB signal centered at 2.37 (J_{AB} = 12−13, $J_{B,3\text{-H(B)}}$ = 7.6, $J_{B,5}$ = 6.4, $J_{B,3\text{-H(A)}}$ = 5.6, 4-H^B), 2.46 (d, $J_{OH,2'}$ = 3.4, 2′-OH), 2.52−2.57 (m, 3-H_2), AB signal (δ_A = 3.46, δ_B = 3.53, J_{AB} = 9.5, in addition split by $J_{A,2'}$ = 7.2, $J_{B,2'}$ = 3.6, 3′-H_2), 4.00 (ddddd, $J_{2',3'\text{-H(A)}} \approx J_{2',1'\text{-H(B)}} \approx$ 7.7, $J_{2',1'\text{-H(A)}} \approx J_{2',3'\text{-H(B)}} \approx J_{2',OH} \approx$ 3.8, 2′-H), 4.57 (s, 1′′-H_2), 4.71 (m_c, presumably interpretable as dddd, $J_{5,4\text{-H(B)}}$ = 8.4, $J_{5,1'\text{-H(A)}} \approx J_{5,4\text{-H(A)}} \approx J_{5,1'\text{-H(B)}} \approx$ 6.5, 5-H), 7.29−7.40 (m, C_6H_5). A 300-MHz H,H correlation spectrum proves the distinction of 1′-H_2 (AB signal, δ_A = 1.80, δ_B = 1.98) because 1′-H^A and 1′-H^B show a cross-peak to 2′-H (δ = 4.00) and 5-H (δ = 4.71) vs. 4-H_2 (AB signal, δ_A = 1.89−1.97, δ_B = 2.37) which shows a (weak) crosspeak to 5-H (δ = 4.71) only. − IR (neat): $\tilde{\nu}$ = 3445 cm^{-1}, 2925, 2865, 1770, 1455, 1365, 1185, 1100, 1015, 915, 740, 700. − $C_{14}H_{18}O_4$ (250.3): calcd. C 67.18, H 7.26; found C 67.45, H 7.49.

(2′R,5R)-4,5-Dihydro-5-[2-hydroxy-3-(triphenylmethoxy)-propyl]-2(3H)-furanone (**14**): Dihydroxylactone **12** (40 mg, 0.25 mmol) in THF (2 ml), NEt_3 (57 μl, 42 mg, 0.41 mmol, 1.6 equiv.), and triphenylmethyl chloride (106 mg, 0.379 mmol, 1.5 equiv.) were stirred for 3 d. After evaporation flash chromatography (2.0 cm, petroleum ether/*t*BuOMe, 1:5) led to the title ether (83 mg, 83%). − $[\alpha]_D^{25}$ = −16.0 (*c* = 1.08, CH_2Cl_2). − ^{1}H NMR (500 MHz, $CDCl_3$, contaminated with *t*BuOMe)*: δ = AB signal (δ_A = 1.73, δ_B = 1.95, J_{AB} = 14.2, in addition split by $J_{A,5}$ = 6.4, $J_{A,2'}$ = 4.1, $J_{B,2'}$ = 8.5, $J_{B,5}$ = 6.9, 1′-H_2*), B part superimposes in part A part of AB signal centered at δ = 1.89 (J_{AB} = 12.8, $J_{A,3\text{-H}(1)} = J_{A,3\text{-H}(2)} = J_{A,5}$ = 9.2, 4-H^A), 2.32 (m_c, 4-H^B), 2.40 (d, $J_{OH,2'}$ = 3.8, OH), 2.48−2.54 (m, 3-H_2), AB signal (δ_A = 3.15, δ_B = 3.23, J_{AB} = 9.6, in addition split by $J_{A,2'}$ = 6.8, $J_{B,2'}$ = 3.8, 3′-H_2), 3.91 (m_c, presumably interpretable as ddddd, $J_{2',1'\text{-H(B)}} \approx J_{2',3'\text{-H(A)}} \approx$ 7−8, $J_{2',OH} \approx J_{2',1'\text{-H(A)}} \approx J_{2',3'\text{-H(B)}} \approx$ 3−4, 2′-H), 4.58 (dddd, $J_{5,4\text{-H(A)}}$ = 8.2, $J_{5,4\text{-H-(B)}} = J_{5,1'\text{-H(A)}} = J_{5,1'\text{-H(B)}}$ = 6.6, 5-H), 7.23−7.28, 7.29−7.34, and 7.40−7.45 (3 m, 15 Ar-H); *assignments in analogy to acetonide **28** and the bis(*tert*-butyldimethylsilyl)ether of diol **12**. − IR ($CDCl_3$): $\tilde{\nu}$ = 3590 cm^{-1}, 3060, 2930, 1770, 1490, 1445, 1355, 1265, 1220, 1180, 1075, 1025, 985, 915, 750, 720. − $C_{26}H_{26}O_4$ (402.5): calcd. C 77.59, H 6.51; found C 77.49, H 6.51.

3-Methylene-6-hepten-1-ol (**17**). − *Procedure A:* At 0°C a solution of 3-methyl-3-buten-1-ol (28.9 ml, 24.7 g, 0.286 mol) in hexane (20 ml) was added dropwise during 15 min to a suspension of KH (13.8 g, 0.343 mol, 1.2 equiv.) in hexane (60 ml). After warming to room temp. and stirring for 1.5 h, one diluted with hexane (50 ml). The mixture was cooled to 0°C. *n*BuLi (1.4 M in hexanes, 204 ml, 0.286 mol, 1.0 equiv.) was added during 45 min. The cooling bath was removed and the mixture stirred for 4.5 h at room temp. Allyl bromide (26.0 ml, 36.3 g, 0.32 mol, 1.05 equiv.) was added and stirring continued overnight. After carefully quenching with MeOH (10 ml) at 0°C H_2O (30 ml) was added and the layers were separated. The aqueous layer was extracted (*t*BuOMe, 2 × 50 ml). The combined organic extracts were dried ($MgSO_4$). Evaporation and distillation (b.p. 55−60°C/0.2 bar) yielded **17** (10.1 g, 28%).

Procedure B: 2-Bromo-1,5-hexadiene (8.18 g, 50.8 mmol) − the first drops neat, the rest diluted with THF (35 ml) − was added dropwise to a suspension of Mg turnings (1.42 g, 58.4 mmol, 1.15

equiv.) in THF (10 ml). The mixture was stirred at 40°C for 2 h. At −30°C the resulting solution was added dropwise to a suspension of CuI (0.968 g, 5.08 mmol, 0.1 equiv.) in THF (50 ml). After 30 min ethylene oxide (2.0 M in THF, 25.4 ml, 50.8 mmol, 1.0 equiv.) was added and 30 min later $BF_3 \cdot OEt_2$ (2.16 g, 1.91 ml, 15.2 mmol, 0.3 equiv.). Stirring was continued at room temp. overnight. The reaction was quenched with satd. aqueous NH_4Cl solution (50 ml). The aqueous layer was extracted with *t*BuOMe (3 × 20 ml). The combined organic extracts were dried with $MgSO_4$. Evaporation of the solvent and distillation (b.p. 38−44°C/0.2 mbar) led to the title compound (5.1 g, 70%).. − IR (neat): $\tilde{\nu}$ = 3345 cm^{-1}, 3075, 2930, 1645, 1445, 1045, 905. − ^1H NMR (500 MHz, $CDCl_3$, slightly contaminated): δ = 2.12−2.19, 2.19−2.25, and 2.28−2.33 (3 m à 2 H, 2-H_2, 4-H_2, 5-H_2), 3.72 (t, $J_{1,2}$ = 6.4, 1-H_2), 4.86 and 4.89 (2 s, 3=CH_2), 4.98 (dm_c, J_{cis} = 10.2, 7-H^E), 5.04 (dm_c, J_{trans} = 17.1, 7-H^Z), 5.82 (ddt, J_{trans} = 16.9, J_{cis} = 10.4, $J_{6,5}$ = 6.5, 6-H); OH resonance not located. − $C_8H_{14}O$ (126.2) calcd. C 76.14, H 11.18; found C 75.75, H 11.57.

O-(3-Methylene-6-heptenyl)-2,2,4,4-tetramethyl-1,3-oxazolidine-3-carboxylate (**20**): Dienol **17** (10.4 g, 82.4 mmol) in THF (25 ml) was added dropwise to solid NaH (2.58 g, 108 mmol, 1.3 equiv.). The resulting suspension was stirred for 30 min. 2,2,4,4-Tetramethyl-1,3-oxazolidine-3-carbonylchloride (17.5 g, 91.3 mmol, 1.1 equiv.) was added and stirring continued for 3 d. The reaction was terminated by the careful addition of water (10 ml) at 0°C. HCl (2 M; 150 ml) was added. Separation of the aqueous layer, extraction with *t*BuOMe (3 × 50 ml), drying (Na_2SO_4/$NaHCO_3$) of the combined organic extracts, and flash chromatography (7.0 cm, petroleum ether/*t*BuOMe, 20:1 → 10:1) provided the title carbamate (18.4 g, 79%). − ^1H NMR (500 MHz, $CDCl_3$): δ = 1.34 und 1.42 [2 s, two rotamers, 4-$(CH_3)_2$], 1.50 and 1.56 [2 s, two rotamers, 2-$(CH_3)_2$], 2.12−2.18, 2.18−2.24, and 2.36−2.46 (3 m à 2 H, 2′-H_2, 4′-H_2, 5′-H_2), 3.72 (s, 5-H_2), 4.22 (m, 1′-H_2), 4.81−4.86 (m, 3′=CH_2), 4.97 (dm_c, J_{cis} = 10.2, 7′-H^E), 5.04 (ddt, J_{trans} = 17.1, J_{allyl} = J_{gem} = 1.6, 7′-H^Z), 5.82 (ddt, J_{trans} = 16.9, J_{cis} = 10.3, $J_{6',5'}$ = 6.4). − IR (film): $\tilde{\nu}$ = 3075 cm^{-1}, 2975, 2930, 2865, 1700, 1645, 1455, 1405, 1350, 1260, 1210, 1155, 1095, 1070, 910, 765. − $C_{16}H_{27}NO_3$ (281.4): calcd. C 68.29, H 9.67, N 4.98; found C 68.10, H 9.63, N 5.05.

(2R)-4-Methylene-7-octene-1,2-diol (**22**): At −78°C, *s*BuLi (1.23 M in hexanes, 80.9 ml, 99.5 mmol, 2.4 equiv.) was added dropwise during 25 min to a solution carbamate **20** (11.66 g, 41.45 mmol), (−)-sparteine (11.71 g, 49.74 mmol, 1.2 equiv.), and a trace of *N*-pivaloyl-*o*-toluidine (for indicating by the color of the derived dilithio species[37] the absolute absence of water) in Et_2O (250 ml). After 3.5 h, DMF (19.13 ml, 18.17 g, 248.7 mmol, 6.0 equiv.) was added and the cooling bath removed. After stirring overnight the reaction mixture was quenched with satd. aqueous phosphate buffer solution (25 ml). The aqueous layer was extracted with *t*BuOMe (2 × 30 ml) and the combined extracts were dried with $MgSO_4$. After evaporation a THF solution (30 ml) of the residue was dropped at 0°C to a suspension of $LiAlH_4$ (4.620 g, 121.8 mmol, 3.0 equiv.) in THF (90 ml). The cooling bath was removed and the mixture refluxed for 3 h. After cooling to 0°C again excess $LiAlH_4$ was destroyed by adding first MeOH (5 ml), then HCl (2 M, 50 ml). The aqueous layer was extracted (*t*BuOMe, 3 × 25 ml). The combined organic layers were dried ($MgSO_4$). After evaporation flash chromatography led to dienediol **22** (4.66 g, 73%). − $[\alpha]_D^{25}$ = −3.15 (*c* = 2.6 in CH_2Cl_2). − ^1H NMR (500 MHz, $CDCl_3$): δ = 2.05 (br. s, 1-OH*), 2.10−2.29 (m, 2-OH*, 3-H_2, 5-H_2, 6-H_2), AB signal (δ_A = 3.50, δ_B = 3.69, J_{AB} = 11.0, in addition split by $J_{A,2}$ = 6.9, B part broadened, 1-H_2), 3.87 (dddd, $J_{2,3\text{-H(1)}}$ = $J_{2,3\text{-H(2)}}$ = $J_{2,1\text{-H(A)}}$ = 6.7, $J_{2,1\text{-H(B)}}$ = 3.0, 2-H), 4.89 (br. s, 4=CH^1), 4.92 (ddt, $J_{gem} \approx J_{allyl} \approx$ 1.6, 4=CH^2), 4.98 (dm_c, J_{cis} = 10.2, 8-H^E), 5.04 (ddt, J_{trans} = 17.1, J_{gem} = J_{allyl} = 1.5, 8-H^Z), 5.82 (dddd, J_{trans} = 16.9, J_{cis} = 10.4, $J_{7,6\text{-H(1)}}$ = $J_{7,6\text{-H(2)}}$ = 6.4, 7-H); *assignments interchangeable. − ^{13}C NMR (126 MHz, $CDCl_3$): δ = 31.77, 35.11, and 40.08 (C-3, C-5, C-6), 66.42 (C-1), 69.72 (C-2), 112.61 and 114.83 (4=CH_2, C-8), 137.97 (C-7), 145.08(C-4). − IR (neat): $\tilde{\nu}$ = 3360 cm^{-1}, 3075, 2930, 1645, 1440, 1080, 1035, 905. − $C_9H_{16}O_2$ (156.2): calcd. C 69.20, H 10.32; found C 69.05, H 10.46.

1-(tert-Butyldiphenylsilyloxy)-4-methylene-7-octen-2-ol (**24**): At 40°C 2-bromo-1,5-hexadiene (5.36 g, 33.3 mmol, 1.4 equiv.) in THF (15 ml) was added dropwise to Mg turnings (925 mg, 38.1 mmol, 1.6 equiv.) suspended in THF (10 ml). After stirring for 30 min at −30°C the mixture was transferred to a suspension of CuI (634 mg, 3.33 mmol, 0.14 equiv.) in THF (30 ml) maintained at the same temperature. After 15 min epoxide **23** (7.43 g, 23.8 mmol) in THF (12 ml) was added dropwise and the mixture warmed to room temp. After stirring overnight the reaction was quenched by adding satd. aqueous KOH/NH_4Cl solution (50 ml). The layers were separated. After extraction (*t*BuOMe) of the aqueous layer, drying ($MgSO_4$) of the organic extracts, and concentrating in vacuo, flash chromatography (7.0 cm, petroleum ether/*t*BuOMe, 20:1) yielded the title compound (7.97 g, 85%). − ^1H NMR (300 MHz, $CDCl_3$): δ = 1.07 [s, $SiC(CH_3)_3$], 2.05−2.25 (m, 3-H_2, 5-H_2, 6-H_2), 2.42 (d, $J_{OH,2}$ = 3.4, OH), AB signal (δ_A = 3.56, δ_B = 3.65, J_{AB} = 10.2, in addition split by $J_{A,2}$ = 6.9, $J_{B,2}$ = 4.0, 1-H_2), 3.86 [ddddd (looking like a qt), $J_{2,3} \approx J_{2,1\text{-H(B)}} \approx$ 6.8, $J_{2,1\text{-H(B)}} \approx J_{2,OH} \approx$ 3.4, 2-H], 4.80 and 4.81 (2 br. s, 1′-H_2), 4.96 (dm_c, J_{cis} = 10.4, 8-H^E), 5.01 (dddd, J_{trans} = 17.2, $J_{gem} \approx J_{allyl}$ = 1.6, 8-H^Z), 5.80 (ddt, J_{trans} = 16.9, J_{cis} = 10.4, $J_{7,6}$ = 6.4, 7-H), 7.35−7.47 and 7.63−7.74 (2 m, 6 und 4 Ar-H, respectively). − The elemental analysis of *R*-**24** has been published.[8a]

rac-4-Methylene-7-octene-1,2-diol (**25**): A solution of silyl ether **24** (322 mg, 0.816 mmol) in THF (7 ml) was treated with *n*Bu_4NF (1 M in THF, 0.90 ml, 0.90 mmol, 1.1 equiv). After 4 h the solvent was removed in vacuo and the residue purified by flash chromatography (2.0 cm, petroleum ether/*t*BuOMe, 1:4) yielding diol **25** (99 mg, 77%). − The ^1H NMR spectral data are identical with the data of the optical active compound **22** (vide supra).

{(2R)-{3-Methylene-1-[(2S)-3,3,3-trifluoro-2-methoxy-2-phenylpropionyl]-6-heptenyl} (2S)-2-methoxy-2-phenyl-3,3,3-trifluoropropionoate (**26**) was prepared from diol **22** and (*R*)-(−)-2-methoxy-2-(trifluoromethyl)acetyl chloride exactly as the **26**/*iso*-**26** mixture was prepared from diol **25**. − ^{19}F NMR (470 MHz, Mosher chloride as internal standard referenced arbitrarily: δ = −71.5): δ = −71.3, −71.2.

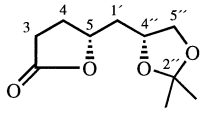
{(2R)-{3-Methylene-1-[(2R)-3,3,3-trifluoro-2-methoxy-2-phenylpropionyl]-6-heptenyl} (2R)-2-methoxy-2-phenyl-3,3,3-trifluoropropionoate (**26**) in a 50:50 mixture with *{(2S)-{3-methylene-1-[(2R)-3,3,3-trifluoro-2-methoxy-2-phenylpropionyl]-6-heptenyl} (2R)-2-methoxy-2-phenyl-3,3,3-trifluoropropionoate* (*iso*-**26**): Dienediol **25** (2.7 mg, 0.017 mmol) in THF (0.5 ml) was treated with (*R*)-(−)-2-methoxy-2-(trifluoromethyl)acetyl chloride (9.0 µl, 12 mg, 0.048 mmol, 2.8 equiv.) and DMAP (7.8 mg, 0.064 mmol, 3.7 equiv.). After stirring for 1 h at room temp. the mixture was filtered over a short pad of silica and the solvent removed under reduced pressure. The NMR spectrum was taken from the ontained crude product. − ^{19}F NMR (470 MHz, Mosher chloride as internal standard referenced arbitrarily: δ = −71.5): δ = −71.4, −71.3, −71.2, −71.1.

Methyl (6R)-6,7-Dihydroxy-4-oxoheptanoate (**27**): At −78°C diene diol **22** (1.413 g, 9.042 mmol) in MeOH (25 ml) was treated with ozone until the blue color persisted. After removing excess

ozone by passing a current of O_2 through the solution the cooling bath was removed. *p*-TsOH (cat.) was added and the mixture stirred at room temp. for 30 min. $NaHCO_3$ (ca. 100 mg) was added and the mixture filtered. The solvent was removed in vacuo and the residue dissolved in *t*BuOMe and evaporated again. This procedure was repeated once to remove traces of MeOH. The residue was dissolved in THF (25 ml) cooled to 0°C, treated with NEt_3 (2.51 ml, 1.83 g, 18.1 mmol, 2.0 equiv.) and Ac_2O (0.94 ml, 970 mg, 9.49 mmol, 1.1 equiv.), and the mixture was refluxed for 2 h. MeOH (2 ml) was added and the solvent removed in vacuo. Flash chromatography of the residue (3.0 cm, *t*BuOMe/MeOH, 30:1) yielded the title compound (1.341 g, 78%). – $[\alpha]_D^{22}$ = +20.0 (*c* = 2.73, CH_2Cl_2). – ^{1}H NMR (500 MHz, $CDCl_3$): δ = 2.61–2.68 and 2.71–2.80 (2 m à 3 H, 2-H_2, 3-H_2, 5-H_2), AB signal (δ_A = 3.52, δ_B = 3.66, J_{AB} = 11.3, in addition split by $J_{A,6}$ = 6.1, $J_{B,6}$ = 3.5, 7-H_2), 3.69 (s, CH_3O), 4.19 (dddd, $J_{6,5\text{-}H(1)}$ = 9.2, $J_{6,7\text{-}H(A)}$ = 6.1, $J_{6,7\text{-}H(B)}$ = 3.2, $J_{6,5\text{-}H(2)}$ = 3.2, 6-H); OH resonances not detected. – IR (neat): $\tilde{\nu}$ = 3410 cm^{-1}, 2950, 1715, 1365, 1210, 1040. – $C_8H_{14}O_5$ (190.2): calcd. C 50.52, H 7.42; found C 50.25, H 7.42.

(4′R,5R)-5-[(2,2-Dimethyl-1,3-dioxolan-4-yl)methyl]-4,5-dihydro-2(3H)-furanone (**28**): Et_3B (1.0 M in THF, 2.47 ml, 2.46 mmol, 2.1 equiv.) in THF (5 ml) and MeOH (1.9 ml) were stirred for 1 h at room temp. After cooling to −78°C keto ester **27** (223 mg, 1.17 mmol) in THF solution (0.8 ml) was added dropwise. After an additional hour at −78°C $NaBH_4$ (36 mg, 1.0 mmol, 0.8 equiv.) was added and the mixture stirred for 3 h at that temperature. The reaction was quenched by adding CF_3COOH (0.3 ml, 3.5 mmol, 3.02 equiv.). After evaporation the residue was dissolved in MeOH and evaporated again. This procedure was repeated six times. Then the residue was dissolved in a mixture of acetone (5 ml) and 2,2-dimethoxypropane (2.0 ml) and treated with CSA (cat.). After 30 min. $NaHCO_3$ (ca. 100 mg) was added and the mixture filtered and evaporated. Flash chromatography (5.0 cm, *t*BuOMe/MeOH 5:1) yielded the title acetonide (118 mg, 63%). – $[\alpha]_D^{23}$ = −41.7 (*c* = 0.825, MeOH). – ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.35 and 1.42 (2′-Me_2), AB signal (δ_A = 1.87, δ_B = 2.12, J_{AB} = 14.1, in addition split by $J_{A,5}$ = $J_{A,4'}$ = 5.7, $J_{B,5}$ = $J_{B,4'}$ = 6.9, 4-CH_2), AB signal (δ_A = 1.99, δ_B = 2.40, J_{AB} = 12.8, in addition split by $J_{A,3\text{-}H(1)}$ = $J_{A,3\text{-}H(2)}$ = 9.6, $J_{A,5}$ = 8.4, $J_{B,3\text{-}H(1)}$ = 7.9*, $J_{B,5}$ = 6.4, $J_{B,3\text{-}H(2)}$ = 5.5*, 4-H_2), 2.53–2.58 (m, 3-H_2), AB signal (δ_A = 3.64, δ_B = 4.10, J_{AB} = 8.0, in addition split by $J_{A,4'}$ = 7.3, $J_{B,4'}$ = 6.0, 5′-H_2), 4.24 (dddd, $J_{4',5'\text{-}H(A)} \approx J_{4',4'\text{-}CH(B)} \approx$ 7.1, $J_{4',5'\text{-}H(B)} \approx J_{4',4'\text{-}CH(A)} \approx$ 5.6, 4′-H), 4.64 (dddd, $J_{5,4\text{-}H(A)}$ = 8.5, $J_{5,4\text{-}H(B)}$ = $J_{5,4'\text{-}CH(A)}$ = $J_{5,4'\text{-}CH(B)}$ = 6.4, 5-H); *assignments interchangeable. A 300 MHz H,H correlation spectrum proves the following assignments: (1) of 4′-CH_2 (AB signal, δ_A = 1.87, δ_B = 2.12) because 4′-CH^A and 4′-CH^B each show a cross-peak to 4′-H (δ = 4.24) and 5-H (δ = 4.64); (2) of 4-H_2 (AB signal, δ_A = 1.99, δ_B = 2.40) because it shows a cross-peak to 5-H (δ = 4.64) only. – IR (neat): $\tilde{\nu}$ = 2985 cm^{-1}, 2940, 2870, 1775, 1455, 1420, 1375, 1220, 1180, 1065, 915, 850. – $C_{10}H_{16}O_4$ (200.2): calcd. C 59.99, H 8.05; found C 59.84, H 8.03.

Scheme 7. Positional numbers of compound **28** to which the ^{1}H-NMR data refer



28

(2′R,5R)-5-[2,3-Bis(benzyloxy)propyl]-4,5-dihydro-2(3H)-furanone (**29**): At −12°C benzyl ether **13** (35 mg, 0.14 mmol) in CH_2Cl_2 (5 ml) was treated with benzyl trichloroacetimidate (34 µl, 46 mg, 0.18 mmol, 1.3 equiv.) and TMSOTf (5.1 µl, 6.2 mg, 0.03 mmol, 0.2 equiv.). Stirring was continued overnight at the same temperature. The reaction was stopped by adding satd. aqueous $NaHCO_3$ solution (2 ml). The aqueous layer was extracted with *t*BuOMe (3 × 7 ml). The combined extracts were dried ($MgSO_4$) and concentrated in vacuo. Flash chromatography (1.5 cm, petroleum ether/*t*BuOMe, 3:2) led to the title compound (24 mg, 50%). – $[\alpha]_D^{25}$ = −2.0 (*c* = 0.685, CH_2Cl_2). – ^{1}H NMR (500 MHz, $CDCl_3$): A part of AB signal centered at δ = 1.80 (J_{AB} = 12.7, in addition split by $J_{A,5}$* = $J_{A,3\text{-}H(1)}$** = 9.7, $J_{A,3\text{-}H(2)}$*,** = 8.4, 4-H^A), AB signal (δ_A = 1.87, δ_B = 2.09, J_{AB} = 14.1, in addition split by $J_{A,5} \approx J_{A,2'} \approx$ 5.9, $J_{B,5}$ = $J_{B,2'}$ = 7.0, 1′-H_2), B part superimposes in part ca. 2.07–2.14 (m, 4-H^B), 2.43–2.48 (m, 3-H_2), AB signal (δ_A = 3.59, δ_B = 3.64, J_{AB} = 10.3, in addition split by $J_{A,2'}$ = 4.5, $J_{B,2'}$ = 4.8, 3′-H_2), 3.73 (dddd, $J_{2',1'\text{-}H(B)}$ = 7.1, $J_{2',1'\text{-}H(A)}$ = $J_{2',3'\text{-}H(A)}$ = $J_{2',3'\text{-}H(B)}$ = 5.0, 2′-H), AB signal# (δ_A = 4.53, δ_B = 4.69, J_{AB} = 11.9, 2′-Ph-CH_2O***), A part superimposed by A part of AB signal# [A part centered at 4.55, B part centered 4.58, J_{AB} = 12.1 (from B part), 3′-Ph-CH_2***] and superimposed by ca. 4.55–4.61 (m, 5-H), 7.27–7.28 (m, 2 × C_6H_5); *, **, ***assignments interchangeable; #which A and B parts belong together was identified by an irradiation experiment: Irradiation at δ = 4.69 (B part) eliminated the AB splitting at δ = 4.53 (A part). – IR ($CDCl_3$): $\tilde{\nu}$ = 2930 cm^{-1}, 2865, 1770, 1455, 1360, 1275, 1185, 1095, 1020, 915, 745, 700. – $C_{21}H_{24}O_4$ (EI): 340.4.

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