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1,3-Diethynylallenes: Stable Monomers, Length-Defined Oligomers, Asymmetric Synthesis, and Optical Resolution

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A series of differently substituted 1,3-diethynylallenes (DEAs) have been synthesized, confirming that the previously introduced construction protocols tolerate a variety of functional groups. The new DEAs bear at least one polar group to facilitate enantiomer separations on chiral stationary phases and to allow further functionalization. They are thermally and environmentally stable compounds since bulky substituents next to the cumulene moiety suppress the tendency to undergo [2+2] cyclodimerization. A series of length-defined oligomers were obtained as mixtures of stereoisomers by oxidative coupling of a monomeric DEA under Glaser–Hay conditions. The electronic absorption data indicate a lack of extended π-electron conjugation across the oligomeric backbone due to the orthogonality of the allenic π-systems. Remarkably, even complex mixtures of stereoisomers only yield one single set of NMR signals, which underlines the low stereodifferentiation in acyclic allenoacetylenic structures. Optical resolution of DEAs represents an amazing challenge, and preliminary results on the analytical level are reported. Asymmetric synthesis by Pd-mediated S_N2'-type cross-coupling of an alkyne to an optically pure bispropargylic precursor opens another promising route to optically active allenes with stereoselectivities currently reaching up to 78 % *ee*.

Introduction

For a long time, since the first discussion by Van't Hoff,[1] allenes have been regarded as a curiosity and considered as unstable. However, the discovery of cumulenic bonds in natural products has risen the attention given to these structures.[2] Moreover, allenes are very interesting reactive intermediates.[3] It is therefore not surprising that much progress has been achieved in the synthesis and the understanding of the properties of this important class of compounds.[4] Thus, allenes bearing two different substituents at each of the two termini (RR′C=C=CRR′) are chiral and the optical stability of enantiomers is high. For 1,3-dimethylallene, the activation free enthalpy for rotational isomerism leading to racemization was determined by Roth and co-workers as $\Delta G^{\neq} = 44.2$ kcal mol^{-1}.[5]

Our group has been involved in the exploration of ethynylated allenes as building blocks for the construction of linear and macrocyclic carbon-rich scaffolds through oxidative acetylenic coupling.[6] Particularly interesting in this regard are 1,3-diethynylallenes (DEAs). The synthesis of DEAs proved however challenging as they tend to quickly dimerize by [2+2] cycloaddition; furthermore, facile isomerizations have been observed.[6d] We were able to circumvent these problems by introducing sterically bulky substituents close to the cumulene moiety.[6b] Following the synthesis of a first series of stable DEAs, we proceeded with the preparation of shape-persistent allenoacetylenic macrocycles with unusual shapes and symmetries and potential host-guesting properties.[6a,7]

Although 1,3-diethynylallenes are axially chiral, we used in all previous work racemic mixtures for acetylenic scaffolding.[6] The reason for this is the still valid finding that the optical resolution of the dialkynylated allenes represents a formidable challenge, even for a research group with large experience in diverse optical resolutions. As a result, acetylenic scaffolding led to complex mixtures of stereoisomers, with diastereoisomer (but not enantiomer) separation succeeding only at the stage of the rigid macrocyclic allenoacetylenes.[6a] Clearly, a versatile access to enantiomerically pure DEAs would be highly desirable, in particular since semi-empirical calculations predict the formation of helical foldamers with distinct conformational preferences upon oxidative acetylenic coupling of enantiomerically pure DEAs.

While the synthesis of optically pure allenes has been well studied,[4f,8] most of the reported routes seem difficult to apply to the preparation of enantiomerically pure DEAs, due to the fact that the two acetylenic substituents provide

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only little possibility for stereodifferentiation. Taking into account mechanistic considerations,[9] it should however be possible to synthesize optically pure DEAs via a Pd-catalyzed S_N2'-type cross-coupling reaction of alkynes to optically pure bispropargylic precursors, as reported for other allenes.[8i,10] Finally, resolution of racemates by high-performance liquid chromatography (HPLC)[11] or separation of intermediately prepared diastereoisomers could also yield the desired optically pure DEAs, although such approaches have found only limited application in the domain of allenes.

In this work, we present the synthesis of new DEAs with polar functional groups introduced with the aim to facilitate enantiomer separations and demonstrate the substantial scope – in terms of different substitution – of the previously reported protocol for the formation of 1,3-dialkynylated allenes.[6b] We report the synthesis of length-defined oligomers by oxidative coupling and demonstrate the lack of extended π-electron delocalization in these systems. Finally, we present our first results in the synthesis and isolation of optically pure DEAs, following both the routes of enantiomer separations and stereoselective synthesis.

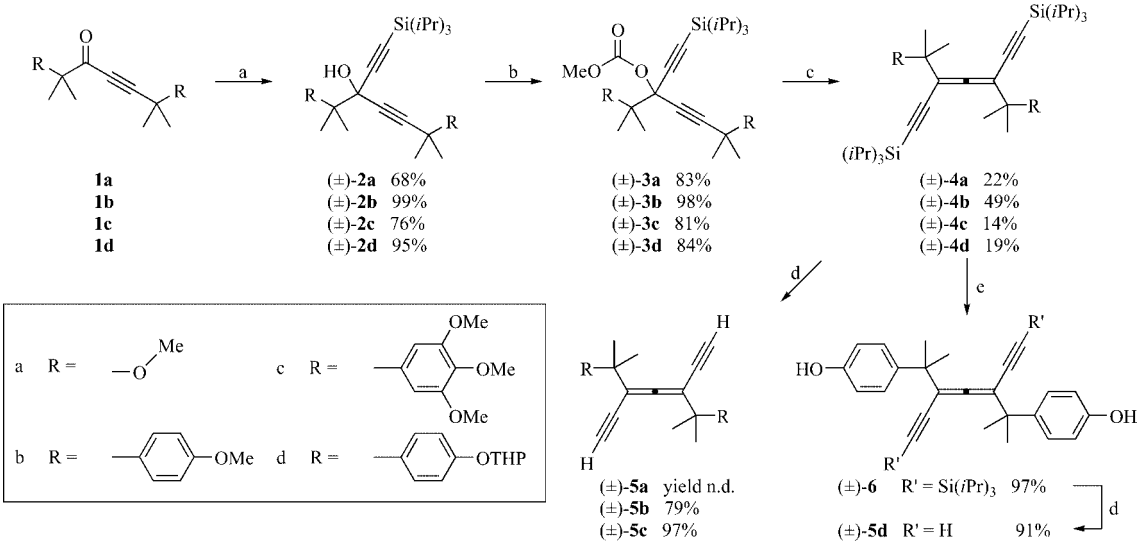
Results and Discussion

Synthesis of Monomeric 1,3-Diethynylallenes with Polar Functional Groups

To assist the synthesis of optically pure allenes, we decided to synthesize allenes bearing at least one polar functional group. On the one hand, the polar group should facilitate the separation by chiral HPLC. On the other hand, this functional group could also be used for the introduction of a chiral auxiliary, leading to the formation of diastereoisomers, which could potentially be separated.

The synthesis of the new monomeric DEAs followed the previously established strategy[6b] and started from ynones **1a**–**d** (Scheme 1). The syntheses of these ynones and their precursors are described with full experimental details in the electronic supporting information. Bispropargylic alcohols (±)-**2a**–**d** were obtained by addition of a protected lithium acetylide in THF. The $(i\text{Pr})_3$Si protecting group was chosen as its steric bulk is needed to control the regiochemistry of the S_N2'-type Sonogashira cross-coupling used to generate the allenes.[6b] The alcohols were then transformed (NaHDMS, MeOCOCl) into the carbonates (±)-**3a**–**d** featuring the bispropargylic leaving group necessary for forming the allenes. The alkyne-protected allenes (±)-**4a**–**d** were finally obtained as stable compounds by Pd-catalyzed S_N2'-type reaction of the carbonates with $(i\text{Pr})_3$Si-protected copper acetylide.[12] Yields of this reaction ($[Pd(PPh_3)_4]$, CuI, Hünig base) were rather low but reproducible; no advantage was found using the pentafluorobenzoate as a better leaving group.[13]

Removal of the alkyne protecting groups with $n\text{Bu}_4$NF in THF yielded the more delicate, unprotected DEAs. The deprotection of the bis(1-methoxy-1-methylethyl) derivative (±)-**4a** proceeded smoothly, although the yield of (±)-**5a** could not be determined and the compound not isolated in pure form since it is highly volatile and evaporates together with the solvent. Its formation was however clearly proved by the appearance of the ethynyl resonance with correct relative intensity (2 H) at δ = 3.09 ppm in the ^{1}H NMR spectrum in $CDCl_3$, with still some solvent (cyclohexane) from the purification present. Allene (±)-**5b** with 1-(4-methoxyphenyl)-1-methylethyl substituents and allene (±)-**5c** with 1-methyl-1-(3,4,5-trimethoxyphenyl)ethyl substituents were isolated in good yields as stable compounds, which can be stored without decomposition under an inert atmosphere at ambient temperature. Crystals of (±)-**5b**, suitable



Scheme 1. Formation of monomeric 1,3-diethynylallenes. a) $(i\text{Pr})_3$Si–C≡C–Li, THF, –78 °C; b) (i) NaHDMS, THF, –78 °C; (ii) MeOCOCl, –78 °C; c) $(i\text{Pr})_3$Si–C≡C–H, CuI, $[Pd(PPh_3)_4]$, Hünig base, $ClCH_2CH_2Cl$; d) $n\text{Bu}_4$NF, THF; e) HCl, THF, H_2O. THF = tetrahydrofuran; NaHDMS = sodium hexamethyldisilazide.

for X-ray crystallography, were obtained by slow evaporation of *n*-hexane, and the crystal structure proved the constitution of the new 1,3-diethynylallene derivative (Figure 1). The stable bisphenol derivative (±)-**5d** was also obtained in high yield by removal of the tetrahydropyran-2-yl (THP) protecting groups (97%) with HCl in THF/H_2O, followed by alkyne deprotection (91%).

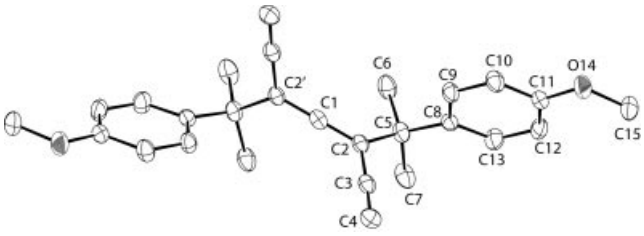


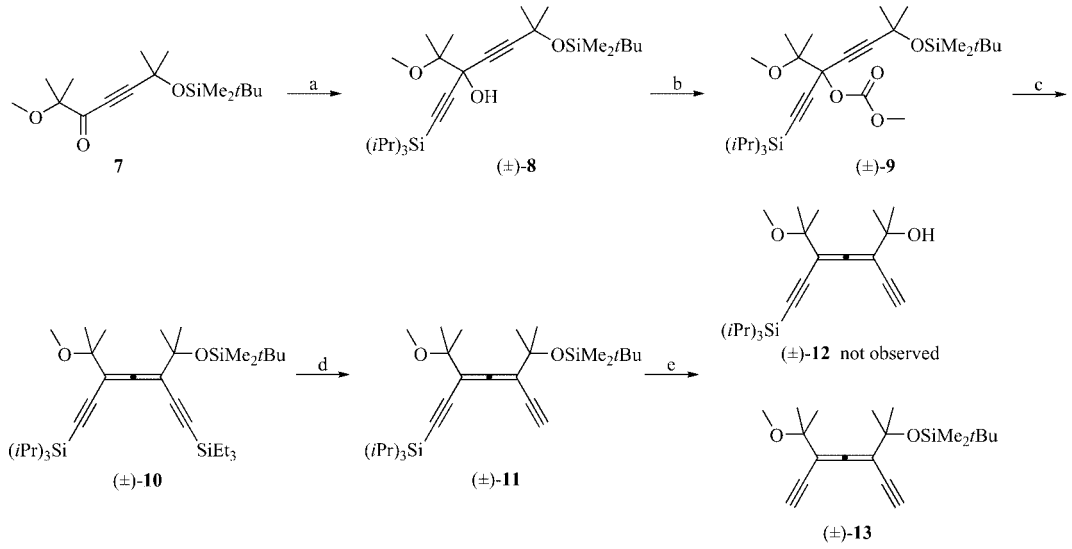
Figure 1. ORTEP plot of (±)-**5b** at 223(2) K with vibrational ellipsoids shown at the 30% probability level. Arbitrary numbering. Selected bond lengths [Å]: C1–C2 1.313(14), C3–C4 1.187(2).

Starting from the ynone **7** with a *t*BuMe$_2$Si ether functionality, we hoped to prepare a DEA derivative ultimately featuring a free aliphatic hydroxy group which could then be esterified with optically active acids with formation of separable diastereoisomers. Furthermore, it was of interest, in view of acetylenic scaffolding, to introduce different alkyne protecting groups. Thus, (*i*Pr)$_3$Si-protected lithium acetylide was added to ynone **7** (see SI) and the resulting alcohol (±)-**8** was converted into carbonate (±)-**9** (Scheme 2). Again, S_N2'-type cross coupling with Et$_3$Si-protected acetylene with formation of allene (±)-**10** was only low-yielding (8%). Selective removal of the Et$_3$Si protecting group with K_2CO_3 in MeOH/THF afforded monodeprotected allene (±)-**11** in 90% yield. Attemps to selectively cleave the *t*BuMe$_2$Si ether with *p*TsOH in wet THF with formation of alcohol (±)-**12** were unsuccessful; rather, the (*i*Pr)$_3$Si group was removed, providing the diethynyl derivative (±)-**13**. Even prolonged stirring in the presence of *n*Bu$_4$NF in THF did not lead to the cleavage of the *t*BuMe$_2$Si ether, but only to removal of the alkyne protecting group.

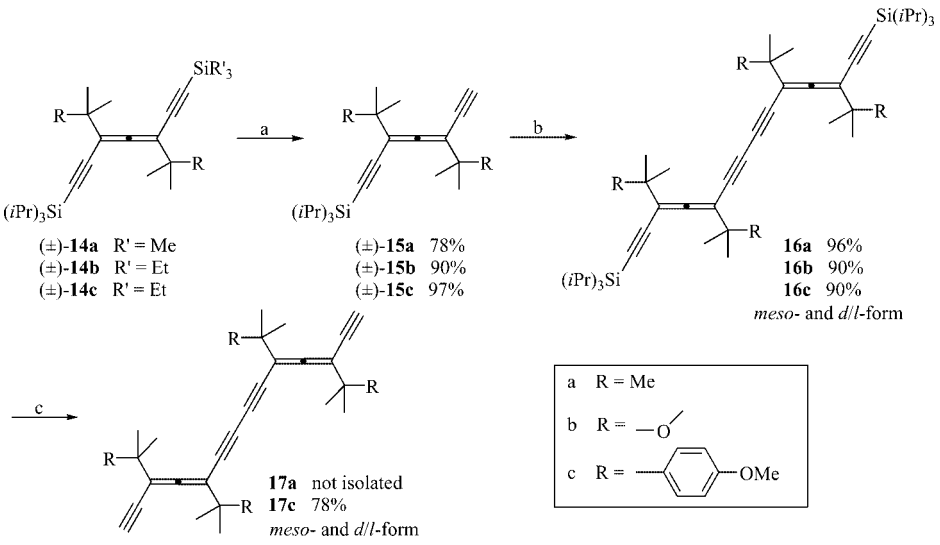
Oligomers

Oligomers and polymers with allenic backbones are only scarcely investigated.[14] DEAs should be ideally suited for oligomerization by oxidative acetylenic coupling with formation of oligomers with an allenoacetylenic backbone. This was first demonstrated with the preparation of a series of dimeric chromophores starting from the differentially protected DEAs (±)-**14a**–**c** (Scheme 3). While (±)-**14a** had been previously reported,[6b] the allenes (±)-**14b**,**c** were synthesized according to the protocols depicted in Scheme 1 and Scheme 2. Again, a more facile separation of the formed dimeric stereoisomers was expected as a result of the introduction of polar ether groups. Selective monodeprotection of (±)-**14a**–**c** with K_2CO_3 in MeOH/THF yielded (±)-**15a**–**c**, and oxidative coupling under Hay conditions provided the corresponding "dimers" **16a**–**c** in excellent yield. Removal of the (*i*Pr)$_3$Si protecting groups was possible and deprotection of **16a** yielded **17a**, which could be used as an "expanded monomer"[15] in oxidative oligomerizations (see below). Compound **17c** with two free ethynyl residues was obtained as a remarkably stable oil, which could be isolated and completely characterized.

Starting from the racemic DEAs (±)-**15a**–**c**, the "dimers" should form as a mixture of stereoisomers, a *meso* and a *d*/*l* form. However, both ^{1}H and ^{13}C NMR spectroscopy only revealed one unique set of resonances! There is, however, no reason to exclude the existence and formation of both *meso*-(*P*,*M*) and *d*/*l*-(*PP*)/(*MM*) forms, despite the fact that we were unable to separate them under various chromato-



Scheme 2. Formation of 1,3-diethynylallene (±)-**13**. a) (*i*Pr)$_3$Si–C≡C–Li, THF, –78 °C, 88%; b) (i) NaHDMS, THF, –78 °C, (ii) MeOCOCl, 86%; c) Et$_3$Si–C≡C–H, CuI, [Pd(PPh$_3$)$_4$], Hünig base, ClCH$_2$CH$_2$Cl, 8%; d) K_2CO_3, MeOH, THF, 90%; e) *p*TsOH, THF or *n*Bu$_4$NF, THF.



Scheme 3. Formation of DEA dimers. a) K_2CO_3, MeOH/THF; b) CuCl, TMEDA, air, acetone; c) nBu$_4$NF, THF. TMEDA = *N*,*N*,*N*′,*N*′-tetramethylethylenediamine.

graphic conditions. We have previously encountered identical NMR spectral behavior as well as practical inseparability of stereoisomeric 1,3-butadiynes bearing stereogenic elements at the two termini such as chiral allenes[6a] or "chiral" methyl groups.[16] Presumably, the large separation between the stereogenic elements created by the buta-1,3-diyne-1,4-diyl spacer, paired with the great ease of rotation about this rod-like fragment, prevent the terminal stereogenic elements from influencing each other differentially in the two diastereoisomeric (*meso* and *d*/*l*) forms, thereby creating close spectral similarity (or even near-identity) and leading to practical inseparability.

By crystallization at low temperature, we were able to grow a small crystal of a *meso*-diastereoisomer, (*P*,*M*)-**16a**, which was suitable for X-ray analysis. The ORTEP plot in Figure 2 shows that a large distance of 10.5 Å is created by the butadiynediyl spacer between the first points of difference in the diastereoisomers, namely the terminal allenic centers C(9) and C(9′). Such spatial distance, paired with the presence of a spacer with no distinct conformational preferences that could transfer the chiral information from one stereogenic element to the other, apparently generates spectral near-identity as well as practical inseparability.

For the synthesis of oligomers by oxidative coupling, we used the end-capping oligomerization of an "expanded monomer", which we had previously applied to the preparation of poly(triacetylene) (PTA) oligomers with lengths up to 18 nm (24-*mer*).[15] Dimeric **16a**, as a mixture of *meso* and *d*/*l* forms, was partially deprotected using nBu$_4$NF in the presence of *o*-nitrophenol (Scheme 4), thereby yielding a mixture of starting material, chain propagating (**17a**), and end-capping (**18**) building blocks. This mixture was submitted without purification to oxidative acetylenic coupling under Hay conditions. After stirring for a few hours at 50 °C, complete conversion was observed. By chromatography on SiO_2, followed by gel permeation chromatography (GPC) over BioBeads S-X1, oligomers of defined length

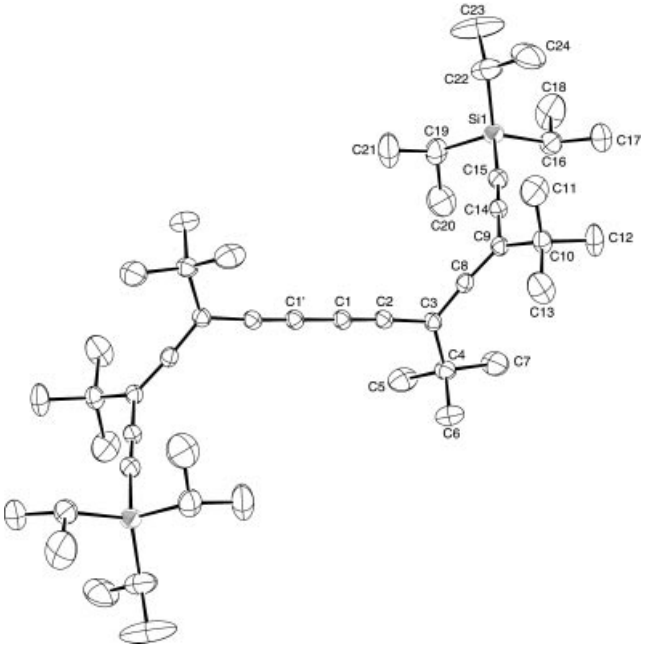
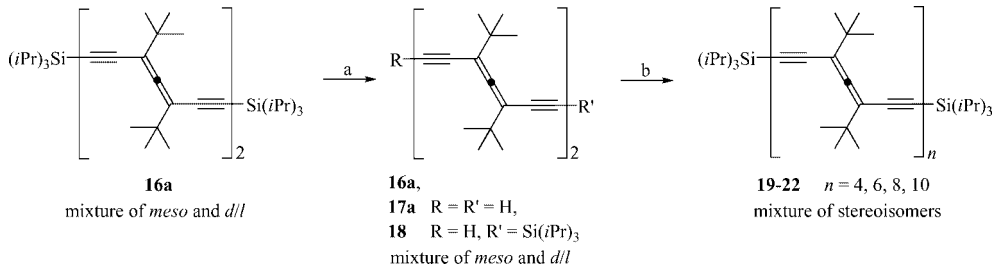


Figure 2. ORTEP plot of (*P*,*M*)-**16a** at 253(2) K with vibrational ellipsoids shown at the 30% probability level. Arbitrary numbering. The distance between C(9) and C(9′) in the crystal amounts to 10.5 Å. Selected bond lengths [Å]: C1–C2 1.201(2), C3–C8 1.312(2), C8–C9 1.312(2), C14–C15 1.204(2).

composed of n = 4 (**19**), 6 (**20**), 8 (**21**), and 10 (**22**) repeat units were obtained. The composition of the oligomers was clearly evidenced by the high-resolution matrix-assisted laser-desorption-ionization mass spectra (HR-MALDI-MS) which showed for each pure oligomer fraction the protonated molecular ion or the $[M + Na]^+$ ion as the base peak. Again, it can be expected that all these oligomers are formed as mixtures of stereoisomers, including pairs of enantiomers as well as achiral diastereoisomers. Similar to the findings for dimeric DEAs discussed above, ^{1}H and ^{13}C



Scheme 4. Formation of oligomeric DEAs with defined length. a) *o*-Nitrophenol (1.3 equiv.), nBu$_4$NF (1.1 equiv.), THF, 20 °C; b) CuCl (0.4 equiv.), equiv. TMEDA (1.4 equiv.), *o*-dichlorobenzene, air, 50 °C.

NMR analysis does not differentiate between the different diastereoisomers in an oligomeric fraction of defined length: only one set of resonances (as would be expected for a single stereoisomer) was obtained. Also, separation of the different diastereoisomers with same oligomeric length was unsuccessful.

The UV/Vis spectra of the oligomers recorded in cyclohexane are shown in Figure 3. Upon passing from monomeric (±)-**23**[6b] to the smallest oligomer, dimeric **16a**, two characteristic bands appear at longer wavelength (296 and 316 nm) that are assigned to the newly formed, longest linearly π-conjugated ene-diyne-ene fragment. Also, the end-absorption shifts bathochromically. In contrast, the positions of the two characteristic longest-wavelength bands and the end-absorption are hardly shifted further upon extending the oligomeric length. The maxima are only weakly shifted upon moving from dimeric **16a** (296, 316 nm) to tetrameric **19** (300, 321), to hexameric **20** (301, 322), to octameric **21** (301, 323), and decameric **22** (302, 324). This optical behavior proves that there is almost no conjugation through the allenic bond in these allenoacetylenic oligomers. The longest π-conjugated ene-diyne-ene chromophore remains the same from the dimer to the decamer, only the number of these chromophoric fragments increases, which is expressed by the amplification of the molar extinction coefficient ε [M^{-1} cm^{-1}] with growing length of the oligomer. This spectral behavior is obviously in sharp contrast to the one observed for poly(triacetylene) oligomers in which the longest conjugated π-chromophore is extended with each addition of a new enediyne repeat unit. Most importantly, the successful oligomerization suggests that the proposed helical foldamer predicted to form from optically active DEA monomers can indeed be prepared in future study.

Towards Optical Resolution of DEAs

Both the separation of enantiomers by high-performance liquid chromatography (HPLC) on chiral stationary phases (CSPs) and derivatization to yield a pair of separable diastereoisomers were pursued on the way to optically active DEAs. However, optical resolution by both methods proved to be a formidable challenge.

As an example for the latter approach, allenes (±)-**5d** and (±)-**6** were treated with (1*S*)-(–)-camphanic chloride leading to the formation of esters **24** and **25**, in both cases as a pair of diastereoisomers (Scheme 5). Unfortunately, these stereoisomers could not be separated chromatographically on a variety of stationary phases or by recrystallization.

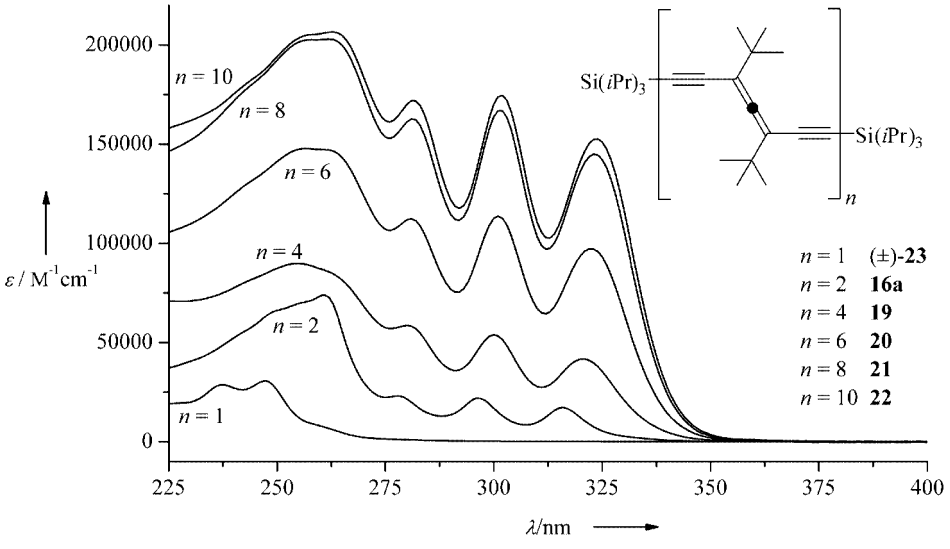
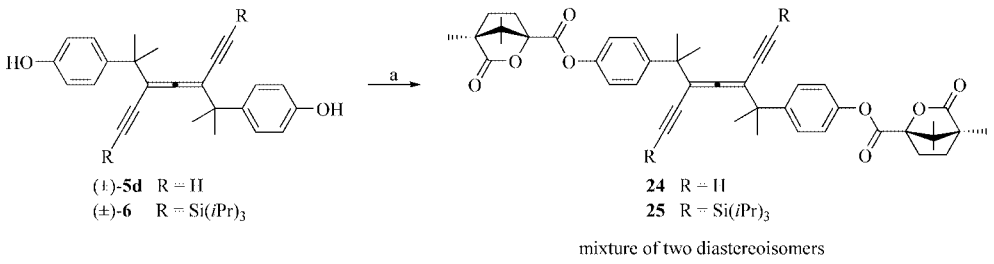


Figure 3. UV/Vis spectra of the different allenoacetylenic oligomers in cyclohexane at 20 °C. All oligomers are present as mixtures of stereoisomers.



Scheme 5. Formation of diastereoisomeric esters for optical resolution. a) (1*S*)-(–)-Camphanic chloride, Hünig base or Et_3N, CH_2Cl_2.

For the separation by HPLC on polar CSPs, several difficulties could be foreseen. Most DEAs are highly apolar, so little interaction with a polar stationary phase is possible. Moreover, stereodifferentiation between the two enantiomers is very low. And finally, low solubility in hexane for some of the DEAs added another challenge to the study. A first series of experiments was conducted with the apolar allenes (±)-**15a** and (±)-**23**. However no satisfying results could be obtained despite the use of various stationary phases (the following columns were used: Chiralcel OJ, Chiralcel OD-R, Chiralpak OT, Whelk-O 1, Cyclobond™ I SN). Retention times were extremely short, even with pure hexane as solvent, showing that there exist indeed only little interactions with the stationary phase. The Cyclobond™ I SN column was also used under reversed phase conditions using MeCN/MeOH or MeCN/$NaClO_4$ as eluents, but without success.

It was expected that the compounds synthesized in this study would show somewhat better behavior on the chiral HPLC columns, as they all feature at least one polar group. However, (±)-**4a**, (±)-**14b**, and (±)-**15b** were eluted quickly even with pure hexane on three different CSPs (Chiralcel OD or OJ and Chiralpak AD). Also (±)-**10** gave no satisfactory result. It seemed that the introduction of a simple methoxy group was not sufficient to achieve a good separation. In the aromatic series, the separation was investigated with silylated allene (±)-**4b**, the unprotected DEA (±)-**5b**, and dimers **16b** and **17b**, which were used as mixtures of *meso*- and *d*/*l*-forms. These experiments showed that the presence of silyl protecting groups needs to be avoided for successful HPLC separation on a CSD. Both (±)-**4b** and (±)-**16b** were eluted quickly without separation. Also, dimer **17b** gave only disappointing results as did (±)-**6** and the camphanic ester **24**.

Preliminary promising results were obtained with the bis(4-methoxyphenyl)-substituted allene (±)-**5b** in collaboration with Emile Cavoy (UCB). Complete separation of the two enantiomers was observed on an analytical Chiralcel AD-H column with a 98:2 pentane/MeOH mixture for the elution (SI). However, these results could not yet be transferred to a preparative column. This ambitious task is currently the subject of a collaboration with Marco Mazzotti (ETH) and will be communicated in due course.

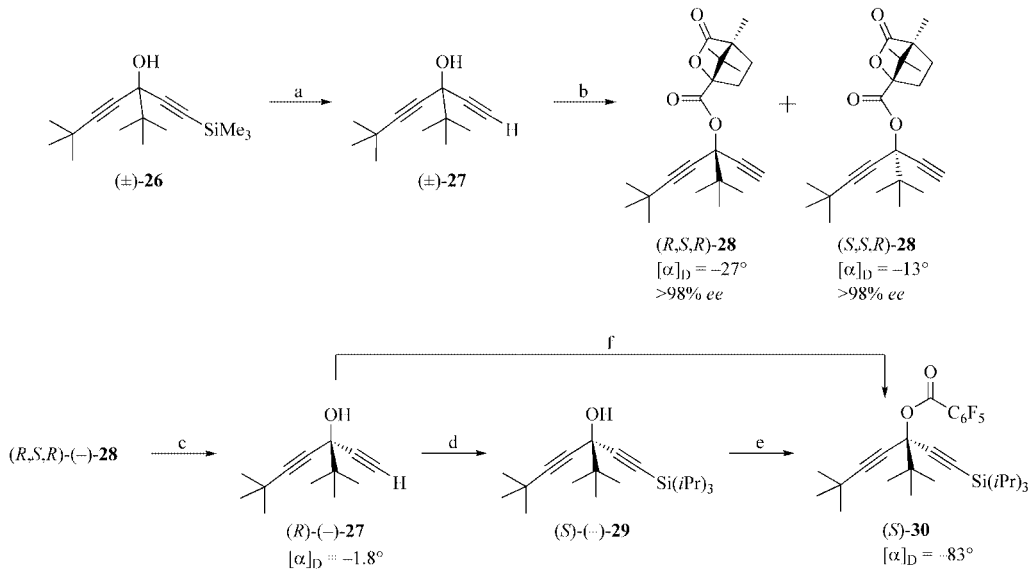
Stereoselective Synthesis of Allenes via Optically Active Bispropargylic Pentafluorobenzoates

On the basis of reports in the literature,[9,10] it seemed possible to synthesize optically pure allenes by stereoselective Pd-catalyzed cross-coupling through *anti* S_N2'-type addition of alkynes to optically pure bispropargylic pentafluorobenzoates. Only two examples of optically active tertiary bispropargylic alcohols have been reported.[17] These compounds could in principle be obtained by asymmetric alkynylation of propargylic ketones. Despite some recent examples of asymmetric alkynylations of ketones,[18] we thought that this approach would not be promising in our case due to lacking stereodifferentiation with two similarly bulky ethynyl residues. We therefore turned to the resolution of diastereoisomeric esters of alcohol (±)-**26**.[6b] As the ester obtained by reaction with (1*S*)-(–)-camphanic chloride was not crystalline and not very stable, we first deprotected (±)-**26** (Scheme 6). Alcohol (±)-**27** was then esterified to give stable, crystalline **28** as a pair of diastereoisomers. Several reaction conditions were tried, and finally coupling with (1*S*)-(–)-camphanic acid in the presence of DMAP and DCC[19] seemed to be the most reproducible, also on a larger scale.

The pure diastereoisomers [≥98% diastereoisomeric excess (*de*)] of ester **28** were obtained by fractional recrystallization (see Experimental Section for details). By X-ray analysis, the absolute (*R*,*S*,*R*)-configuration could be assigned to the less soluble isomer (Figure 4). Both isomers could also be separated on neutral Al_2O_3 (activity I), which allowed purification of the more soluble diastereoisomer.

Diastereomerically pure esters (*R*,*S*,*R*)-**28** and (*S*,*S*,*R*)-**28** were then hydrolyzed under basic conditions in MeOH/THF (Scheme 6). To prove that no racemization occurred during the saponification process, part of alcohol (*R*)-(–)-**27** was resubmitted to esterification with (1*S*)-(–)-camphanic chloride. The corresponding ester was obtained diastereomerically pure. The free alkyne was then silylated and alcohol (*S*)-(–)-**29** transformed into the perfluorobenzoate (*S*)-**30**.[6a] As *O*-silylation was not observed, (*S*)-(–)-**29** was not isolated but perfluorobenzoyl chloride added directly to the intermediate alkoxide.

With the enantiomerically pure precursor (*S*)-**30** in hands, the cross-coupling to the optically pure allene (*P*)-



Scheme 6. Preparation of the optically active bispropargyl pentafluorobenzoate (*S*)-**30**. a) K_2CO_3, MeOH/THF, 63%; b) (1*S*)-(–)-camphanic acid, DMAP, DCC, CH_2Cl_2, 59%; c) 1 M NaOH aq, MeOH/THF, 20 °C, 94%; d) (i) *n*BuLi, THF, –78 °C; (ii) $(iPr)_3SiCl$, –78 °C to 20 °C; e) (i) LiHMDS, THF, 0 °C; (ii) C_6F_5COCl, 0 °C→20 °C; f) (i) *n*BuLi, THF, –78 °C; (ii) $(iPr)_3SiCl$; (iii) C_6F_5COCl, –78 °C→20 °C, 30–40%. DMAP = 4-(dimethylamino)pyridine; DCC = dicyclohexylcarbodiimide; LiHMDS = lithium hexamethyldisylazide.

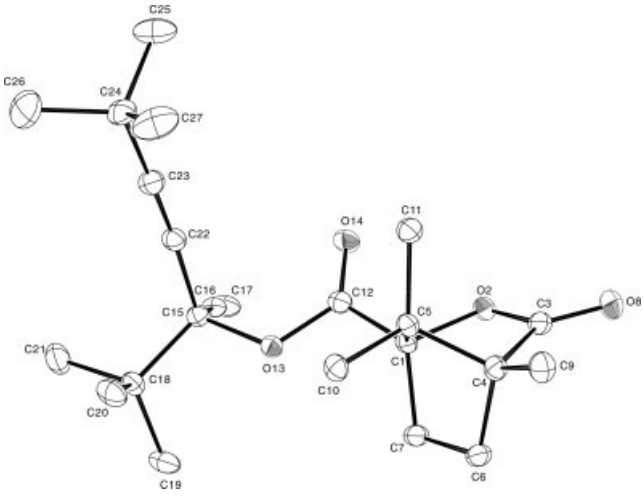
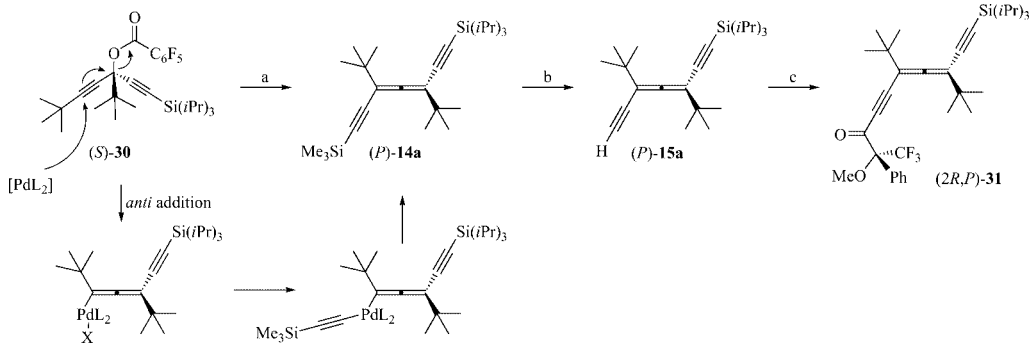


Figure 4. ORTEP plot of (*R*,*S*,*R*)-**28** at 220 K with vibrational ellipsoids shown at the 30% probability level. Arbitrary numbering.

14a, resulting from *anti*-addition of $Me_3Si–C\equiv CH$, as proposed in the literature,[9] was investigated (Scheme 7). The absolute configuration of the allene was assigned based on the reaction mechanism. The Pd° complex attacks the triple bond *anti* to the leaving group. As the acetylene is introduced by a reductive elimination, the overall addition remains *anti*. Unfortunately, we were not able to prove this assumption. Different conditions were applied, and the details of this investigation can be found in the Supporting Information. To determine the optical purity of DEAs (*P*)-**14a** and mono-deprotected (*P*)-**15a**, the latter was transformed into the propargyl-substituted Mosher ketone (*R*,*P*)-**31**.[20] Reaction with the chloride of the Mosher acid[21] gave the best results of ketone, but the yields remained low. Optimization of the reaction conditions was studied with racemic allene, but it was unsuccessful. It provided, however, proof that both diastereoisomers were formed at the same rate. ^1H NMR integration of (*R*,*P*)-**31**



Scheme 7. a) $Me_3Si–C\equiv C–H$, $[Pd(PPh_3)_4]$, CuI, Cy_2NMe (2×0.2 equiv.), toluene, 20 °C, 24 h, 28%; b) K_2CO_3, MeOH/THF, 98%; c) (i) *n*BuLi, THF/hexane; (ii) (*R*)-MTPA-Cl, –78 °C→20 °C, 35%. Cy = cyclohexyl; MTPA = (*R*)-1-methoxy-1-(trifluoromethyl)phenylacetyl chloride.

and its minor diastereoisomer (*R*,*M*)-**31** allowed the determination of the diastereoisomeric excess. Assuming that no racemization occurred during $SiMe_3$ deprotection and synthesis of the Mosher ketone, the optical purity of (*P*)-**14a** and (*P*)-**15a** could be established.

The best result was obtained in toluene at 20 °C with Cy_2NMe (0.4 equiv.) as base. In this case, the enantiomeric excess (*ee*) of the allene was 78%, but the yields were low with only 25%. At this moment, it is difficult to advance any conclusions on the parameters influencing the diastereoselectivity. Further research is currently carried out to get a clearer picture of the reaction.

Conclusions

This paper demonstrates the substantial scope of our previously described method to synthesize stable 1,3-diethynylallenes (DEAs). Many of the new DEAs bear polar functional groups for further derivatization; furthermore, such polar groups are required for a successful optical resolution by HPLC on chiral stationary phases. Even with terminally deprotected ethynyl groups, the new derivatives are stable as a result of the steric bulk around the allene core. Without bulky substituents directly shielding the allene core, DEAs are unstable and undergo reactions such as [2+2] cycloadditions.

Terminally deprotected DEAs are versatile building blocks for higher-order two- and three-dimensional scaffolds by oxidative acetylenic coupling. A range of dimeric DEAs as well as an oligomeric series with up to ten repeat units were prepared starting from racemic monomer and fully characterized. However, stereodifferentiation in these stable allenoacetylenic chromophores is poor and the various stereoisomers could not be separated. As a result of a lack of diastereodifferentiation, all stereoisomers in oligomers of a given length show identical NMR spectroscopic properties, i.e. the ^1H and ^{13}C NMR spectra only feature one unique set of resonances. The UV/Vis spectra of the different oligomers clearly confirm that π-electron conjugation across allenes with their orthogonal π-systems is strongly limited: the positions of the longest wavelength bands are nearly unchanged upon moving from dimeric to decameric oligomer.

The poor enantiodifferentiation in 1,3-diethynylallenes is also apparent in the formidable challenge we encountered in the optical resolution of these compounds. Nevertheless, promising results have finally been obtained with analytical samples. Efforts to transfer the conditions to preparative-scale separations are underway, but remain quite challenging. Similarly, optical resolutions through the intermediacy of diastereoisomeric derivatives have so far not been successful.

Finally, asymmetric synthesis by Pd-mediated S_N2'-type cross-coupling of an alkyne to optically pure bispropargylic pentafluorobenzoates – scarcely known intermediates – looks promising and already yielded optically active allenes with stereoselectivities currently reaching up to 78% *ee*. Further work in this direction is currently underway.

Experimental Section

Materials and General Methods: Reagents and solvents were purchased at reagent grade from Acros, Aldrich, and Fluka, and used as received. THF was freshly distilled from Na/benzophenone under N_2. Toluene was freshly distilled from Na under N_2. CH_2Cl_2 was freshly distilled from CaH under N_2. All reactions were performed under an inert atmosphere by applying a positive pressure of N_2 unless otherwise noted. Flash chromatography (FC) was carried out with SiO_2 60 (particle size 0.040–0.063 mm, 230–400 mesh; Fluka) and distilled technical solvents. Thin-layer chromatography (TLC) was conducted on aluminum sheets coated with SiO_2 60 F_{254} obtained from Macherey–Nagel; visualization with a UV lamp (254 or 366 nm) and potassium permanganate or cerium molybdate staining. The chiral stationary phases tested for optical resolutions of racemic DEAs by HPLC and the solvent mixtures used are shown in a Table in the electronic supporting information (see also the footnote on the first page of this paper). Melting points (m.p.) were measured with a Büchi B-540 melting-point apparatus in open capillaries and are uncorrected. ^1H NMR and ^{13}C NMR spectra were measured with a Varian Gemini 300, a Varian Mercury 300, or a Bruker ARX300 at 300 and 75 MHz respectively. Chemical shifts are reported in ppm relative to the signal of Me_4Si. Residual solvent signals in the ^1H and ^{13}C NMR spectra were used as an internal reference. Coupling constants (*J*) are given in Hz. The apparent resonance multiplicity is described as s (singlet), br. s (broad singlet), d (doublet), t (triplet), q (quartet), and m (multiplet). Infrared spectra (IR) were recorded with a Perkin–Elmer Spectrum BX instrument. UV/Vis spectra were recorded with a Varian Cary-5 spectrophotometer. The absorption wavelenghts are reported in nm with the molar extinction coefficient ε ($M^{-1}cm^{-1}$) in brackets; shoulders are indicated as sh. High-resolution (HR) EI-MS spectra were measured with a Hitachi–Perkin–Elmer VG-Tribrid spectrometer. HR FT-MALDI spectra were measured with an IonSpec Ultima Fourier transform (FT) instrument with [(2*E*)-3-(4-*tert*-butylphenyl)-2-methylprop-2-enylidene]malononitrile (DCTB) or 3-hydroxypicolinic acid (3-HPA) as matrix. The most important signals are reported in *m*/*z* units with M as the molecular ion. Elemental analyses were performed at the Laboratorium für Organische Chemie, ETH Zürich, with a LECO CHN/900 instrument.

General Method A, Synthesis of the Bispropargylic Tertiary Alcohol: *n*BuLi (1.6 M in THF, 1.25 equiv.) was added to a solution of monoprotected acetylene (1.15 equiv.) in THF (15 mL) at –78 °C. After stirring for 15 min at –78 °C and 15 min at 20 °C, the solution was cooled to –78 °C and the ynone (1 equiv., ca 4 mmol) dissolved in THF (5 mL) added. The mixture was stirred at –78 °C, 0 °C or 20 °C until completion and quenched by adding a saturated aq. NH_4Cl solution (50 mL). The aq. layer was extracted with Et_2O (3 × 50 mL). The combined organic layers were washed with a saturated aq. NaCl solution (100 mL), dried with Na_2SO_4, and evaporated under reduced pressure.

General Method B, Synthesis of the Bispropargylic Carbonate from the Corresponding Tertiary Alcohol: NaHDMS (1 M solution in THF, 1.1 equiv.) was added to a solution of alcohol (1 equiv.) in THF (15 mL) at –78 °C. After stirring for 15 min at –78 °C and 15 min at 20 °C, the mixture was re-cooled to –78 °C and methyl chloroformate (1.25 equiv.) added. The mixture was allowed to reach 20 °C and stirred until completion. It was then quenched by adding a saturated aq. NH_4Cl solution (50 mL). The aq. layer was extracted with Et_2O (3 × 50 mL). The combined organic layers were washed with a saturated aq. NaCl solution (100 mL), dried with Na_2SO_4, and evaporated under reduced pressure.

General Method C, Synthesis of the Allene by Sonogashira Cross-Coupling: In a small flask, a mixture of CuI (0.1 equiv.) and $[Pd(PPh_3)_4]$ (0.1 equiv.) was dried under vacuum to remove all moisture and oxygen. $ClCH_2CH_2Cl$ (2.5 mL) was added and Ar bubbled through the mixture for 5 min. In a Schlenk flask, a solution containing carbonate (1 equiv., ca 220 μmol) and $(iPr)_3Si$–acetylene (12 equiv.) in $ClCH_2CH_2Cl$ (5 mL) and Hünig base (5 mL) was degassed for 5 min. It was then heated to 80 °C, and the catalyst suspension was added. The mixture was stirred until all the carbonate was consumed as observed by TLC. It was then poured into a saturated aq. NH_4Cl solution (50 mL), followed by extraction with CH_2Cl_2 (3 × 25 mL). The combined organic layers were washed with water (50 mL), dried with Na_2SO_4, and evaporated under reduced pressure.

General Method D, Selective Et_3Si-Alkyne Deprotection with K_2CO_3: The allene (1 equiv.) was dissolved in THF (5 mL), and methanol (5 mL) and K_2CO_3 (47 equiv.) were added. The mixture was stirred for 14 h at 20 °C and then poured into water (50 mL). The aq. layer was extracted with Et_2O (3 × 25 mL), then the combined organic layers were washed with water (3 × 25 mL), dried with Na_2SO_4, and evaporated under reduced pressure.

General Method E, $(iPr)_3Si$-Alkyne Deprotection with nBu_4NF: The allene was dissolved in THF, and a 1.0 M solution of nBu_4NF in THF was added. After stirring until completion, water was added and the mixture extracted with Et_2O (3×). The combined organic layers were washed with water, dried with Na_2SO_4, and evaporated under reduced pressure.

(±)-6-(4-Methoxyphenyl)-3-[1-(4-methoxyphenyl)-1-methylethyl]-6-methyl-1-(triisopropylsilyl)hepta-1,4-diyn-3-ol [(±)-2b]: Following general method A, (±)-**2b** was obtained from **1b** (1.42 g, 4.06 mmol) as a colorless oil in 99% yield after purification by flash chromatography (FC) (SiO_2; cyclohexane/EtOAc, 8:1, R_f = 0.45). ^1H NMR (300 MHz, $CDCl_3$): δ = 1.09 (m, 21 H), 1.51 (s, 3 H), 1.54 (s, 3 H), 1.62 (s, 6 H), 2.13 (s, 1 H), 3.79 (s, 3 H), 3.80 (s, 3 H), 6.80–6.83 (m, 4 H), 7.38 (d, J = 8.7 Hz, 2 H), 7.51 (d, J = 8.7 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 11.4, 18.7, 24.3, 24.7, 31.5, 31.6, 35.3, 45.9, 55.17, 55.22, 71.1, 81.6, 85.6, 91.6, 106.9, 112.6, 113.3, 126.5, 129.7, 135.2, 138.7, 157.8, 158.1 ppm. IR (film): $\tilde{\nu}$ = 3455, 2940, 2863, 2358, 1611, 1512, 1462, 1382, 1361, 1297, 1249, 1181, 1036, 828, 668 cm^{-1}. MS (MALDI): m/z (%) = 555 (45) $[M + Na]^+$, 516 (42), 515 (100), 235. MALDI-HRMS: m/z calcd. for $C_{34}H_{48}NaO_3^+$: 555.3273, found 555.3273. $C_{34}H_{48}O_3Si$ (532.82): calcd. C 76.64, H 9.08; found C 76.75, H 8.97.

(±)-4-(4-Methoxyphenyl)-1-[1-(4-methoxyphenyl)-1-methylethyl]-4-methyl-1-[(triisopropylsilyl)ethynyl]pent-2-yn-1-yl Methyl Carbonate [(±)-3b]: Following general method B, (±)-**3b** was obtained from (±)-**2b** (2.00 g, 3.76 mmol) as a colorless oil in 93% yield after purification by FC (SiO_2; cyclohexane/EtOAc, 16:1, R_f = 0.33). ^1H NMR (300 MHz, $CDCl_3$): δ = 1.07 (m, 21 H), 1.49 (s, 3 H), 1.51 (s, 3 H), 1.64 (s, 6 H), 3.72 (s, 3 H), 3.78 (s, 3 H), 3.79 (s, 3 H), 6.77–6.83 (m, 4 H), 7.38 (d, J = 8.7 Hz, 2 H), 7.52 (d, J = 9.0 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 11.2, 18.5, 24.2, 24.6, 31.3, 31.4, 35.4, 46.0, 54.3, 55.0, 55.1, 76.8, 78.2, 88.1, 93.4, 102.9, 112.3, 113.4, 126.7, 130.1, 135.0, 138.7, 152.6, 158.0, 158.2 ppm. IR (film): $\tilde{\nu}$ = 2927, 2863, 1766, 1512, 1457, 1248, 1181, 1037, 629 cm^{-1}. MS (MALDI): m/z (%) = 629 (30) $[M + K]^+$, 613 (56) $[M + Na]^+$, 516 (45), 515 (100), 477 (61). MALDI-HRMS: m/z calcd. for $C_{36}H_{50}NaO_5Si^+$: 613.3328, found 613.3331; m/z calcd. for $C_{36}H_{50}KO_5Si^+$: 629.3067, found 629.3083.

(±)-{3,5-Bis[1-(4-methoxyphenyl)-1-methylethyl]-3,4-hepta-1,6-dienediyne-1,7-diyl}bis(triisopropylsilane) [(±)-4b]: Following general method C, (±)-**4b** was obtained from (±)-**3b** (283 mg, 0.479 mmol) as a colorless oil in 49% yield after purification by FC (SiO_2; cyclohexane/CH_2Cl_2, 3:1, R_f = 0.15). ^1H NMR (300 MHz, $CDCl_3$): δ = 1.00 (m, 42 H), 1.44 (s, 6 H), 1.46 (s, 6 H), 3.78 (s, 6 H), 6.78 (d, J = 9.0 Hz, 4 H), 7.17 (d, J = 9.0 Hz, 4 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 11.4, 18.7, 28.4, 28.6, 42.6, 55.2, 94.4, 100.3, 104.2, 113.1, 127.5, 139.0, 157.6, 214.0 ppm. IR (film): $\tilde{\nu}$ = 2940, 2863, 2359, 2143, 1612, 1151, 1462, 1250, 1182, 1038, 882, 827, 668 cm^{-1}. UV/Vis (n-hexane): λ_{max} (ε) = 227 (39300), 240 (42700), 250 (43100). MS (EI): m/z (%) = 696 (0.7) $[M]^+$, 539 (2.7), 149 (100). EI-HRMS: m/z calcd. for $C_{45}H_{68}O_2Si_2^+$: 696.4758, found 696.4756. $C_{45}H_{68}O_2Si_2$ (697.19): calcd. C 77.52, H 9.83; found C 77.46, H 9.69.

(±)-3,5-Bis[1-(4-methoxyphenyl)-1-methylethyl]hepta-3,4-diene-1,6-diyne [(±)-5b]: Following general method E, (±)-**5b** was obtained from (±)-**4b** (80 mg, 115 μmol) as a white solid in 79% yield after purification by FC (SiO_2; cyclohexane/EtOAc, 16:1, R_f = 0.25). ^1H NMR (300 MHz, $CDCl_3$): δ = 1.45 (s, 6 H), 1.49 (s, 6 H), 2.92 (s, 2 H), 3.80 (s, 6 H), 6.84 (d, J = 8.6 Hz, 4 H), 7.19 (d, J = 8.6 Hz, 4 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 28.5, 28.6, 42.6, 55.2, 77.2, 81.1, 103.3, 113.2, 127.3, 138.5, 157.7, 213.9 ppm. MS (EI): m/z (%) = 356 (1), 314 (28), 313 (100). MS (ESI): m/z (%) = 407 $[M + Na]^+$; no exact mass or correct elemental analysis could be obtained.

(*P*,*M*)- and (*P*,*P*)/(*M*,*M*)-3,5,10,12-Tetrakis(*tert*-butyl)-1,14-bis(triisopropylsilyl)tetradeca-3,4,10,11-tetraene-1,6,8,13-tetrayne (16a):[6b] To a solution of **15a**[6b] (90 mg, 0.252 mmol, 1.0 equiv.) in $ClCH_2CH_2Cl$ (4 mL), a solution of TMEDA (30 μL, 0.206 mmol, 0.8 equiv.) and CuCl (7.4 mg, 0.075 mmol, 0.3 equiv.) in $ClCH_2CH_2Cl$ (1 mL) were added. The resulting mixture was stirred in an open flask for 3 h at 50 °C. Cyclohexane was added and the organic layer washed twice with a saturated aq. NH_4Cl solution. The combined aq. layers were extracted with cyclohexane. The organic layer was dried with $MgSO_4$, filtered, and the solvents evaporated. The residue was filtered through SiO_2 (cyclohexane). Compound **16a** (86 mg, 0.122 mmol, 96%) was obtained as a mixture of an enantiomeric pair and a diastereoisomeric *meso*-isomer. Colorless solid. R_f = 0.49 (SiO_2; hexane); m.p. 110–118 °C. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.08 (s, 42 H), 1.14 (s, 36 H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 11.3, 18.6, 28.9, 29.0, 35.5, 35.9, 75.3, 76.9, 94.9, 99.6, 102.4, 104.6, 214.2 ppm. IR (KBr): $\tilde{\nu}$ = 2963, 2865, 2142, 1464, 1394, 1363, 1241, 1108, 1069, 1018, 996, 883, 863, 754, 678 cm^{-1}. UV/Vis (n-hexane): λ_{max} (ε) = 222, (sh, 40900), 249 (sh, 75400), 255 (sh, 80300), 261 (85400), 277 (25700), 296 (26300), 316 (22400). MS (EI): m/z (%) = 710.5 (52) $[M]^+$, 695.5 (11) $[M - Me]^+$, 667.4 (16) $[M - Pr]^+$, 653.4 (46) $[M - tBu]^+$, 625.4 (11), 553.4 (5) $[M - Si(iPr)_3]^+$, 312.3 (12), 157.2 (53) $[Si(iPr)_3]^+$, 115.1 (53), 87.1 (32), 73.1 (49), 57.1 (89) $[tBu]^+$, 44.0 (100) $[Pr]^+$. $C_{48}H_{78}Si_2$ (711.30): calcd. C 81.05, H 11.05; found C 81.03, H 11.16.

(±)-[3,5-Bis(1-methoxy-1-methylethyl)-7-(triethylsilyl)hepta-3,4-diene-1,6-diyn-1-yl](triisopropyl)silane [(±)-14b]: Following general method C, (±)-**14b** was obtained from (±)-**3a** (301 mg, 687 μmol) and Et_3Si–acetylene as a colorless oil in 28% yield after purification by FC (SiO_2; cyclohexane/EtOAc, 16:1, R_f = 0.43). ^1H NMR (300 MHz, $CDCl_3$): δ = 0.62 (q, J = 7.9 Hz, 6 H), 1.00 (t, J = 7.9 Hz, 9 H), 1.08 (m, 21 H), 1.36 (s, 3 H), 1.37 (s, 3 H), 1.39 (s, 6 H), 3.24 (s, 3 H), 3.25 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 4.6, 7.6, 11.4, 18.7, 25.5, 25.7, 25.8, 26.1, 50.9, 51.0, 76.6 (2×), 95.9, 96.8, 97.9, 98.4, 99.3, 99.7, 215.5 ppm. IR (film): $\tilde{\nu}$ = 2943, 2865, 2357, 2340, 2141, 1464, 1378, 1362, 1178, 1112, 1075 cm^{-1}. EI-HRMS: m/z calcd. for $C_{30}H_{54}O_2Si_2^+$: 502.3662, found 502.3657. $C_{48}H_{78}O_2Si_2$ (743.30): calcd. C 71.65, H 10.82; found C 71.70, H 10.79.

(±)-[3,5-Bis(1-methoxy-1-methylethyl)hepta-3,4-diene-1,6-diyn-1-yl]-(triisopropyl)silane [(±)-15b]: Following general method D, (±)-**15b** was obtained from (±)-**14b** (39.0 mg, 77.7 μmol) in 90% yield after purification by FC. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.07 (m, 21 H), 1.36 (s, 3 H), 1.37 (s, 3 H), 1.38 (s, 3 H), 1.40 (s, 3 H), 3.06 (s, 1 H), 3.24 (s, 3 H), 3.25 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 11.2, 18.6, 25.2, 25.4, 25.6, 26.0, 50.9, 51.0, 75.8, 76.6, 81.5 (2×), 96.5, 98.0, 98.1, 100.5, 215.4 ppm. IR (film): $\tilde{\nu}$ = 2941, 2864, 2141, 1463, 1378, 1362, 1177, 1150, 1074, 882, 668 cm^{-1}. MS (EI): *m*/*z* (%) = 388 (1) $[M]^+$, 373 (5), 73 (100). EI-HRMS: *m*/*z* calcd. for $C_{24}H_{40}O_2Si^+$: 388.2802, found 388.2998.

(*P*,*M*)- and (*P*,*P*)/(*M*,*M*)-3,5,10,12-Tetrakis(1-methoxy-1-methylethyl)-1,14-bis(triisopropylsilyl)tetradeca-3,4,10,11-tetraene-1,6,8,13-tetrayne (16b): TMEDA (0.70 g, 6.03 mmol) and CuCl (124 mg, 1.25 mmol) were suspended in acetone (3 mL) and stirred for 15 min. The resulting suspension was filtered and a solution of allene **15b** (14.3 mg, 36.8 μmol, 1 equiv.) in acetone (1 mL) added. The mixture was stirred overnight in an open flask and then poured into a saturated aq. NH_4Cl solution (10 mL) and extracted with Et_2O (4 × 10 mL). The combined organic layers were washed with water (2 × 25 mL), dried (Na_2SO_4), and all volatiles were removed under reduced pressure. The product **16b** (12.8 mg, 16.5 μmol, 90%) was purified by FC (SiO_2; cyclohexane/EtOAc, 8:1, R_f = 0.42). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.07 (m, 42 H), 1.36 (s, 6 H), 1.38 (s, 6 H), 1.39 (s, 6 H), 1.40 (s, 6 H), 3.24 (s, 6 H), 3.26 (s, 6 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 11.2, 18.6, 25.1, 25.7, 25.8, 26.2, 51.0, 51.2, 73.9, 76.7, 77.1, 77.8, 97.2, 97.6, 98.5, 101.2, 217.0 ppm. IR (neat): $\tilde{\nu}$ = 2979, 2940, 2864, 2141, 1733, 1463, 1378, 1362, 1177, 1074, 668 cm^{-1}. MS (MALDI): *m*/*z* (%) = 813 $[M + K]^+$, 798 $[M + Na]^+$, 744, 711, 456. MALDI-HRMS: *m*/*z* calcd. for $C_{48}H_{78}NaO_5Si^+$: 797.5341, found 797.5316; *m*/*z* calcd. for $C_{48}H_{78}KO_5Si^+$: 813.5080, found 813.5035.

(±)-{3,5-Bis[1-(4-methoxyphenyl)-1-methylethyl]-7-[triethylsilyl]-hepta-3,4-diene-1,6-diyn-1-yl}(triisopropyl)silane [(±)-14c]: Following general method C, (±)-**14c** was obtained from (±)-**3b** (153 mg, 0.259 mmol) as a colorless oil in 46% after purification by FC (SiO_2; cyclohexane/CH_2Cl_2, 5:2, R_f = 0.27). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.54 (q, *J* = 7.8 Hz, 6 H), 0.93 (t, *J* = 7.8 Hz, 9 H), 0.99 (m, 21 H), 1.41 (s, 3 H), 1.44 (s, 3 H), 1.46 (s, 6 H), 3.77 (s, 3 H), 3.78 (s, 3 H), 6.77 (d, *J* = 8.7 Hz, 2 H), 6.79 (d, *J* = 8.7 Hz, 2 H), 7.13 (d, *J* = 8.7 Hz, 2 H), 7.17 (d, *J* = 8.7 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 4.5, 7.4, 11.2, 18.5, 28.2, 28.3, 28.5, 28.6, 42.6 (2×), 55.1 (2×), 94.5, 95.6, 99.9, 100.3, 104.1, 104.3, 113.1 (2×), 127.6 (2×), 139.0, 139.1, 157.8 (2×), 214.0 ppm. IR (film): $\tilde{\nu}$ = 2953, 2864, 2359, 2140, 1611, 1512, 1462, 1301, 1251, 1038, 883, 827, 631 cm^{-1}. MS (EI): *m*/*z* (%) = 654 (1.2) $[M]^+$, 149 (100). EI-HRMS: *m*/*z* calcd. for $C_{42}H_{62}O_2Si_2^+$: 654.4288, found 654.4297.

(±)-{3,5-Bis[1-(4-methoxyphenyl)-1-methylethyl]hepta-3,4-diene-1,6-diyn-1-yl}(triisopropyl)silane [(±)-15c]: Following general method D, (±)-**15c** was obtained from (±)-**14c** (200 mg, 306 μmol) in 97% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.99 (m, 21 H), 1.43 (s, 3 H), 1.45 (s, 3 H), 1.46 (s, 3 H), 1.49 (s, 3 H), 2.90 (s, 1 H), 3.79 (s, 6 H), 6.80 (m, 4 H), 7.15 (d, *J* = 9.0 Hz, 2 H), 7.21 (d, *J* = 9.0 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 11.3, 18.6, 28.25, 28.37, 28.67, 28.71, 42.6 (2×), 55.1, 55.2, 77.5, 80.5, 95.1, 99.8, 102.6, 104.9, 113.12, 113.21, 127.36, 127.44, 138.67, 138.77, 157.7 (2×), 213.8 ppm. IR (film): $\tilde{\nu}$ = 3282, 2940, 2863, 2360, 2141, 1609, 1512, 1462, 1251, 1182, 1036, 883, 827, 633 cm^{-1}. MS (MALDI): *m*/*z* = 563 (100) $[M + Na]^+$. MALDI-HRMS: *m*/*z* calcd. for $C_{36}H_{48}O_2Si^+$: 563.3324, found 563.3308.

(*P*,*M*)- and (*P*,*P*)/(*M*,*M*)-1,14-Bis(triisopropylsilyl)-3,5,10,12-tetrakis[1-(4-methoxyphenyl)-1-methylethyl]tetradeca-3,4,10,11-tetraene-1,6,8,13-tetrayne (16c): A mixture of CuCl (124 mg, 0.014 mmol) and TMEDA (700 mg, 6.03 mmol) in acetone (10 mL) was stirred for 5 min at 20 °C. The suspension was filtered, and 1 mL of the resulting blue solution was added to a solution of allene **15c** (36 mg, 66.6 μmol) in acetone (1 mL). After stirring the mixture overnight, it was poured into a saturated aq. NH_4Cl solution (25 mL) and extracted with Et_2O (3 × 15 mL). The organic layers were collected, dried (Na_2SO_4), and the residue obtained after the removal of all organic volatiles was purified by FC (SiO_2; cyclohexane/EtOAc, 16:1, R_f = 0.31) providing the desired compound as a colorless oil (32 mg, 29.6 μmol, 90%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.99 (m, 42 H), 1.37 (s, 6 H), 1.468 (s, 6 H), 1.476 (s, 6 H), 1.48 (s, 6 H), 3.77 (s, 6 H), 3.80 (s, 6 H), 6.78 (d, *J* = 9.1 Hz, 4 H), 6.83 (d, *J* = 8.8 Hz, 4 H), 7.08 (d, *J* = 9.1 Hz, 4 H), 7.22 (d, *J* = 8.8 Hz, 4 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 11.2, 18.6, 28.0, 28.7 (3 ×), 42.8, 43.1, 55.1, 55.2, 75.4, 95.7, 99.5, 103.3, 105.3, 113.2, 113.4, 127.5, 127.6, 138.7, 138.8, 157.8, 157.9, 215.8 ppm, two singlets were not observed. IR (film): $\tilde{\nu}$ = 2940, 2862, 2360, 2340, 1511, 1463, 1251, 1182, 1036, 828 cm^{-1}. MS (MALDI): *m*/*z* = 1102 $[M + Na]^+$, 1080 $[M + H]^+$. MALDI-HRMS: *m*/*z* calcd. for $C_{72}H_{95}O_4Si_2^+$: 1079.677, found 1079.675; *m*/*z* calcd. for $C_{72}H_{94}NaO_4Si_2^+$: 1101.659, found 1101.656; *m*/*z* calcd. for $C_{72}H_{94}KO_4Si_2^+$: 1117.633, found 1117.641.

(*P*,*M*)- and (*P*,*P*)/(*M*,*M*)-3,5,10,12-Tetrakis[1-(4-methoxyphenyl)-1-methylethyl]tetradeca-3,4,10,11-tetraene-1,6,8,13-tetrayne (17c): Following general method E, **17c** was obtained from **16c** (29 mg, 26.9 μmol) as a colorless oil in 78% yield after purification by FC (SiO_2; cyclohexane/EtOAc, 4:1, R_f = 0.50). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.41 (s, 6 H), 1.46 (s, 6 H), 1.47 (s, 6 H), 1.49 (s, 6 H), 2.93 (s, 2 H), 3.80 (s, 6 H), 3.81 (s, 6 H), 6.82 (d, *J* = 8.7 Hz, 4 H), 6.84 (d, *J* = 9.0 Hz, 4 H), 7.14 (d, *J* = 8.7 Hz, 4 H), 7.20 (d, *J* = 9.0 Hz, 4 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 28.2, 28.5, 28.6, 28.8, 42.6, 42.9, 55.2, 75.2, 77.6, 81.6, 104.1, 113.3, 113.4, 127.5, 138.5, 157.9, 215.8 ppm. IR (film): $\tilde{\nu}$ = 3283, 2963, 2924, 2360, 2343, 1511, 1251, 1181, 1035, 829, 668 cm^{-1}. MS (MALDI): *m*/*z* (%) = 805 $[M + K]^+$, 789 $[M + Na]^+$, 767 $[M + H]^+$. MALDI-HRMS: *m*/*z* calcd. for $C_{54}H_{55}O_4^+$: 767.4103, found 767.4080; *m*/*z* calcd. for $C_{54}H_{54}NaO_4^+$: 789.3923, found 789.3914; *m*/*z* calcd. for $C_{54}H_{54}KO_4^+$: 806.3662, found 806.3634.

Synthesis of Diethinylallene Oligomers: The dimer **16a** (267 mg, 0.375 mmol, 1.0 equiv.) and *o*-nitrophenol (66 mg, 0.472 mmol, 1.3 equiv.) were dissolved in THF (20 mL) and cooled to 0 °C. *n*Bu_4NF (414 μL of a 1 M solution in THF, 0.414 mmol, 1.1 equiv.) was added, and the solution turned immediately to a bright yellow. The mixture was allowed to reach 10 °C over a period of 1 h and stirred at 20 °C for 7.5 h. It was then evaporated under reduced pressure. The resulting brightly yellow solution was filtered through SiO_2 (hexane, ca. 250 mL). The solvent was evaporated, and a yellow oil was obtained (224 mg, quant.). Analysis by GPC showed that the allene was nearly completely deprotected.

The residue was dissolved in *o*-dichlorobenzene (10 mL), and a solution of CuCl (15 mg, 0.153 mmol, 0.4 equiv.) and TMEDA (76 μL, 0.526 mmol, 1.4 equiv.) in *o*-dichlorobenzene (1 mL) was added. The flask was put into a preheated oil bath (50 °C), and the mixture was stirred for 8 h in an open flask. The mixture was then filtered through SiO_2 (hexane, 10 mL and hexane/CH_2Cl_2, 100 mL), to separate from the Cu complexes. Analytical GPC (Shodex GPC KF-802.5 and Shodex GPC KF-803L, THF) showed complete conversion of the dimer and appearance of oligomeric products. The solution was concentrated under reduced pressure, and the *o*-dichlorobenzene was distilled off under vacuum. A yellow solid (226 mg) was obtained. The different oligomers could be

separated by chromatography (SiO_2; hexane/CH_2Cl_2:100:0 → 50:1 → 25:1 → 20:1 → 10:1 → 5:1). The dimer eluted first (43 mg, 60 μmol, 16%), followed by the tetramer (20 mg, 18 μmol, 10%), hexamer (18 mg, 12 μmol, 10%), octamer (17 mg, 9 μmol, 9%), decamer (13 mg, 6 μmol, 7%), and finally the higher oligomers (15 mg). The fractions were analyzed by analytical GPC. Further purification of the oligomers of identical length (but as a mixture of stereoisomers) was realized by preparative GPC (BioBeads S-X1, CH_2Cl_2).

3,5,10,12,17,19,24,26-Octakis(*tert*-butyl)-1,28-bis(triisopropylsilyl)-octacosa-3,4,10,11,17,18,24,25-octaene-1,6,8,13,15,20,22,27-octayne (19): Mixture of stereoisomers; colorless solid; m.p. 95–99 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.08 (s, 42 H), 1.139 (s, 18 H), 1.142 (s, 18 H), 1.150 (s, 18 H), 1.154 (s, 18 H) ppm. ^{1}H NMR (300 MHz, C_6D_6): δ = 1.00 (s, 18 H), 1.01 (s, 18 H), 1.08 (s, 42 H), 1.13 (s, 18 H), 1.16 (s, 18 H) ppm. ^{13}C NMR (75 MHz, C_6D_6): δ = 11.8, 18.9, 29.0, 29.05, 29.1, 35.8, 36.2, 75.2, 75.7, 76.1, 78.1, 78.6, 78.8, 95.4, 100.2, 103.3, 104.2, 104.4, 105.1, 214.4, 215.8 ppm. IR (solid): $\tilde{\nu}$ = 2962, 2925, 2865, 2899, 2141 (*w*), 1475, 1458, 1392 (*w*), 1362, 1072 (*w*), 995 (*w*), 882, 668. UV/Vis (cyclohexane): λ_{max} (ε) = 255 (111900), 264 (sh, 105300), 280 (76300), 300 (75100), 321 (62900). MS (MALDI): *m*/*z* (%) = 1244 (23) [M + Na + Si(*i*Pr)$_2$]$^+$, 1130 (100) [M + Na]$^+$, 1108 (46) [M + H]$^+$. MALDI-HRMS: *m*/*z* calcd. for $C_{78}H_{114}NaSi_2^+$: 1129.8351, found 1129.8366. $C_{78}H_{114}Si_2$ (1107.93): calcd. C 84.56, H 10.37; found C 84.60, H 10.53.

3,5,10,12,17,19,24,26,31,33,38,40-Dodecakis(*tert*-butyl)-1,42-bis-(triisopropylsilyl)dotetraconta-3,4,10,11,17,18,24,25,31,32,38,39-dodecaene-1,6,8,13,15,20,22,27,29,34,36,41-dodecayne (20): Mixture of stereoisomers; colorless solid; m.p. >130 °C (with decomposition). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.08 (s, 42 H), 1.138 (s, 18 H), 1.141 (s, 18 H), 1.15 (s, 72 H) ppm. ^{1}H NMR (300 MHz, C_6D_6): δ = 1.004 (s, 9 H), 1.007 (s, 9 H), 1.024 (s, 27 H), 1.026 (s, 27 H), 1.12 (s, 42 H), 1.13 (s, 18 H), 1.17 (s, 18 H) ppm. ^{13}C NMR (125 MHz, C_6D_6): δ = 11.7, 18.8, 28.92, 28.98 (2×), 29.1, 35.7, 36.11, 36.14, 75.1, 75.59, 75.64, 75.71, 76.1, 78.1, 78.5, 78.62, 78.64, 78.8, 95.5, 100.3, 103.3, 104.3, 104.41, 104.42, 104.45, 105.1, 214.7, 216.04, 216.06, 216.08, 216.10 ppm. IR (solid): $\tilde{\nu}$ = 2961, 2926, 2864, 2899, 2141 (*w*), 1915 (*w*), 1474, 1460, 1362, 1392, 1220, 1071, 882, 750, 678, 665 cm^{-1}. UV/Vis (cyclohexane): λ_{max} (ε) = 256 (147800), 266 (sh, 140600), 281 (112400), 301 (113800), 322 (97200). MS (MALDI): *m*/*z* (%) = 1641 (23) [M + Na + Si(*i*Pr)$_2$]$^+$, 1527 (78) [M + Na]$^+$, 1505 (100) [M + H]$^+$. MALDI-HRMS: *m*/*z* calcd. for $C_{108}H_{150}NaSi_2^+$: 1527.1199, found 1527.1216.

3,5,10,12,17,19,24,26,31,33,38,40,45,47,52,54-Hexadecakis(*tert*-butyl)-1,56-bis(triisopropylsilyl)hexapentaconta-3,4,10,11,17,18,24,25,31,32,38,39,45,46,52,53-hexadecaene-1,6,8,13,15,20,22,27,29,34,36,41,43,48,50,55-hexadecayne (21): Mixture of stereoisomers; colorless solid; m.p. >140° (with decomposition). ^{1}H NMR (500 MHz, C_6D_6): δ = 1.006 (*s*, 9 H), 1.009 (*s*, 9 H), 1.026 (*s*, 27 H), 1.030 (*s*, 63 H), 1.12 (*s*, 42 H), 1.14 (*s*, 18 H), 1.17 (*s*, 18 H) ppm. ^{13}C NMR (75 MHz, C_6D_6): δ = 11.6, 18.8, 28.89, 28.96, 29.05, 35.7, 36.10, 36.13, 75.2, 75.67, 75.74, 76.1, 78.1, 78.5, 78.6, 78.8, 95.5, 100.3, 103.3, 104.3, 104.4, 105.1, 214.7, 216.1 ppm. IR (solid): $\tilde{\nu}$ = 2961, 2925, 2865, 2899, 2141 (*w*), 1917 (*w*), 1473, 1460, 1393, 1362, 1220, 1066, 882, 750, 678, 665 cm^{-1}. UV/Vis (cyclohexane): λ_{max} (ε) = 258 (202500), 262 (202900), 281 (162700), 301 (166800), 323 (144900). MS (MALDI): *m*/*z* (%) = 2037 (25) [M + Na + Si(*i*Pr)$_2$]$^+$, 1923 (100) [M + Na]$^+$, 1901 (66) [M + H]$^+$, 1843 (24) [M – *t*Bu]$^+$, 1787 (36) [M – 2 *t*Bu]$^+$, 1731 (27) [M – 3 *t*Bu]$^+$. MALDI-HRMS: *m*/*z* calcd. for $C_{138}H_{186}NaSi_2^+$: 1923.4017, found 1923.4040.

3,5,10,12,17,19,24,26,31,33,38,40,45,47,52,54,59,61,66,68-Icosakis-(*tert*-butyl)-1,70-bis(triisopropylsilyl)heptaconta-3,4,10,11,17,18,24,25,31,32,38,39,45,46,52,53,59,60,66,67-icosaene-1,6,8,13,15,20,22,27,29,34,36,41,43,48,50,55,57,62,64,69-icosayne (22): Mixture of stereoisomers; m.p. >150 °C (slow decomposition). ^{1}H NMR (500 MHz, C_6D_6): δ = 1.009 (*s*, 9 H), 1.013 (*s*, 9 H), 1.03 (*s*, 126 H), 1.13 (*s*, 42 H), 1.14 (*s*, 18 H), 1.17 (*s*, 18 H) ppm. ^{13}C NMR (75 MHz, C_6D_6): δ = 11.6, 18.8, 28.9, 29.0, 35.7, 36.1, 75.2, 75.6, 76.1, 78.1, 78.5, 78.8, 95.5, 100.3, 103.3, 104.4, 105.1, 214.7, 216.1 ppm. IR (solid): $\tilde{\nu}$ = 2956, 2925, 2863, 2139 (*w*), 1917 (*w*), 1456, 1460, 1390, 1362, 1220, 1066, 882, 667 cm^{-1}. UV/Vis (cyclohexane): λ_{max} (ε) = 254 (sh, 232300), 263 (237800), 281 (197000), 302 (202500), 324 (175700). MS (MALDI): *m*/*z* (%) = 2320 (100) [M + Na]$^+$, 2298 (18) [M + H]$^+$. MALDI-HRMS: *m*/*z* calcd. for $C_{168}H_{222}NaSi_2^+$: 2319.6834, found 2319.6859.

(±)-3-(*tert*-Butyl)-6,6-dimethylhepta-1,4-diyn-3-ol [(±)-27]: Alcohol (±)-**26**[6b] (1.667 g, 6.303 mmol, 1.0 equiv.) was dissolved in THF (40 mL). MeOH (40 mL) and K_2CO_3 (0.437 g, 3.151 mmol, 0.5 equiv.) were added and the suspension stirred for 5 h under air. Et_2O was then added and the organic layer washed with a saturated aq. NH_4Cl solution. The aq. layer was extracted with Et_2O (ca. 50 mL). The combined organic layers were washed with H_2O, dried with Na_2SO_4, and evaporated under reduced pressure. The resulting oil (1.11 g, 5.77 mmol, 92%) was purified by FC (SiO_2; cyclohexane/EtOAc, 10:1). Alcohol (±)-**27** was obtained as a volatile colorless liquid (0.738 g, 3.838 mmol, 61%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.11 (s, 9 H); 1.23 (s, 9 H), 2.31 (br. s, 1 H), 2.50 (s, 1 H). ^{13}C NMR (75 MHz, $CDCl_3$): δ = 24.7, 27.4, 30.8, 39.9, 70.6, 71.7, 78.1, 84.0, 92.9 ppm. IR (film): $\tilde{\nu}$ = 3466 (w br.), 3311 (w), 2968, 2930, 2870, 2244 (w), 1728 (w), 1477, 1459, 1363, 1264, 1064, 999, 964, 882, 649, 631 cm^{-1}. MS (EI): *m*/*z* (%) = 191 (<1) [M]$^+$, 177 (12) [M – Me]$^+$, 136 (53) [M + H – *t*Bu]$^+$, 135 (52) [M – *t*Bu]$^+$, 69 (100), 57 (88) [*t*Bu]$^+$. EI-HRMS: *m*/*z* calcd. for $C_{12}H_{17}O^+$: 177.1279, found 177.1276. $C_{13}H_{20}O$ (192.30): calcd. C 81.20, H 10.48, O 8.32; found C 81.37, H 10.44, O 8.35.

(1*R*)-1-*tert*-Butyl-1-ethynyl-4,4-dimethylpent-2-yn-1-yl (1*S*,4*R*)-4,7,7-Trimethyl-3-oxo-2-oxabicyclo[2.2.1]heptane-1-carboxylate [(*R*,*S*,*R*)-28] and (1*S*)-1-*tert*-Butyl-1-ethynyl-4,4-dimethylpent-2-yn-1-yl (1*S*,4*R*)-4,7,7-Trimethyl-3-oxo-2-oxabicyclo[2.2.1]heptane-1-carboxylate [(*S*,*S*,*R*)-28]: Alcohol (±)-**27** (1.5 g, 7.8 mmol, 1.0 equiv.) was dissolved in dry CH_2Cl_2 (15 mL). DMAP (480 mg, 0.5 equiv.) and (1*S*)-(–)-camphanic acid (1.7 g, 1.1 equiv.) were added, and the mixture was cooled to 0 °C. A solution of DCC (1.92 g, 1.2 equiv.) in CH_2Cl_2 (15 mL) was added. The mixture was stirred at 20 °C for 16 h. Then, the solids were removed by filtration. The filtrate was washed twice with 0.2 N HCl and twice with H_2O. The organic layer was dried with $MgSO_4$ and evaporated under reduced pressure. The product was purified by FC (SiO_2; cyclohexane/EtOAc, 10:0→10:1) and obtained as a mixture of 2 diastereoisomers (*R*,*S*,*R*)- and (*S*,*S*,*R*)-**28** (1.72 g, 4.62 mmol, 59%). The esters were dissolved in a small amount of CH_2Cl_2, and cyclohexane was added. Slow evaporation of the solvent gave colorless needles. The supernatant was pipetted off and the crystals [841 mg, ≥98% *de* of (*R*,*S*,*R*)-isomer] were washed with a little cyclohexane or pentane. Further evaporation of the mother liquid gave crystals enriched in the other isomer [76% *de* of the (*S*,*S*,*R*)-isomer]. The resulting mother liquid was enriched in the (*S*,*S*,*R*)-isomer (68% *de*). Repeated fractional recrystallization led to diastereomerically pure product (≥98% *de*, as determined by ^{1}H NMR of the alkyne proton). Alternatively, fractions enriched in (*S*,*S*,*R*)-isomer could be separated into the two isomers by FC over Al_2O_3 N (activity I, cyclohexane/EtOAc, 10:1).

(*R*,*S*,*R*)-28: Colorless crystals. $[\alpha]_D$ = –27 ($CHCl_3$, *c* = 1.0); m.p. 154–157 °C. ^1H NMR (300 MHz. $CDCl_3$): δ = 1.00 (s, 3 H), 1.06 (s, 3 H), 1.11 (s, 3 H), 1.17 (s, 9 H), 1.22 (s, 9 H), 1.67 (ddd, *J* = 4.2, 9.3, 13.2 Hz, 1 H), 1.91 (ddd, *J* = 4.8, 10.8, 13.2 Hz, 1 H), 2.04 (ddd, *J* = 4.5, 9.3, 13.5 Hz, 1 H), 2.46 (ddd, *J* = 4.2, 10.8, 13.5 Hz, 1 H), 2.61 (s, 1 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 9.8, 16.89, 16.93, 24.9, 27.6, 29.0, 30.1, 30.6, 40.7, 54.7, 54.9, 74.09, 74.15, 75.5, 79.4, 91.0, 95.2, 164.3, 178.2 ppm. IR (solid): $\tilde{\nu}$ = 3253, 2971, 2239 (w), 2114 (w), 1774 (s), 1758 (s), 1476, 1310, 1259, 1111, 1052 (s), 934, 885, 739, 701 cm^{-1}. MS (EI): *m*/*z* (%) = 372 (20) $[M]^+$, 357 (19) $[M – Me]^+$, 182 (68), 164 (55), 136 (100), 83 (77), 57 (67) $[t\text{Bu}]^+$. EI-HRMS: *m*/*z* calcd. for $C_{23}H_{32}O_4^+$: 372.2301, found 372.2302. $C_{23}H_{32}O_4$ (372.50): calcd. C 74.16, H 8.66, O 17.18; found C 74.14, H 8.48, O 17.21.

(*S*,*S*,*R*)-28: Colorless crystals. $[\alpha]_D$ = –13 ($CHCl_3$, *c* = 1.0); m.p. 116.7–118.9 °C. ^1H NMR (300 MHz, $CDCl_3$): δ = 1.00 (s, 3 H), 1.05 (s, 3 H), 1.11 (s, 3 H), 1.17 (*s*, 9 H), 1.2 (s, 9 H), 1.67 (ddd, *J* = 4.2, 9.3, 13.5 Hz, 1 H), 1.91 (ddd, *J* = 4.5, 10.8, 13.2 Hz, 1 H), 2.04 (ddd, *J* = 4.5, 9.3, 13.5 Hz, 1 H), 2.48 (ddd, *J* = 4.2, 10.8, 13.5 Hz, 1 H), 2.62 (s, 1 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 9.8, 16.89, 16.93, 24.9, 27.6, 29.0, 30.1, 30.6, 40.7, 54.7, 54.9, 74.09, 74.15, 75.5, 79.4, 91.0, 95.2, 164.3, 178.2 ppm. IR (solid): $\tilde{\nu}$ = 3241, 2967, 1780 (s), 1749 (s), 1457, 1312, 1263 (s), 1100 (s), 1051 (s), 928, 884, 733 cm^{-1}. MS (EI): *m*/*z* (%) = 372 (9) $[M]^+$, 357 (6) $[M – Me]^+$, 316 (6) $[M + H – t\text{Bu}]^+$, 182 (48), 164 (30), 136 (30), 83 (24), 57 (28) $[t\text{Bu}]^+$, 17.97 (100) $[H_2O]^+$. EI-HRMS: *m*/*z* calcd. for $C_{23}H_{32}O_4^+$: 372.2301, found 372.2289. $C_{23}H_{32}O_4$ (372.50): calcd. C 74.16, H 8.66, O 17.18; found C 74.11, H 8.50, O 17.14.

(3*R*)-3-*tert*-Butyl-6,6-dimethylhepta-1,4-diyn-3-ol [(*R*)-27]: (*R*,*S*,*R*)-**28** (313 mg, 0.840 mmol, ≥ 98% *de*) was dissolved in THF (5 mL), and a 1 M solution of NaOH (1 mL) and MeOH (2 mL) were added. The mixture was stirred for 2 h under air. More NaOH solution (0.1 mL) was added, and after 40 min the solution was diluted with Et_2O and washed with a saturated aq. NH_4Cl solution and H_2O. The organic layer was dried with Na_2SO_4 and evaporated under reduced pressure to yield a slightly yellow oil, which was filtered through SiO_2 (cyclohexane/EtOAc, 10:1). Evaporation gave a colorless liquid (154 mg, 0.801 mmol, 95%), which became solid after storage at 4 °C. Colorless solid. $[\alpha]_D$ = –1.8 ($CHCl_3$, *c* = 1.0); m.p. 39.1–40.2 °C.

(3*S*)-3-(*tert*-Butyl)-6,6-dimethylhepta-1,4-diyn-3-ol [(*S*)-27]: (*S*,*S*,*R*)-**28** (108 mg, 0.289 mmol, ≥ 98% *de*) was dissolved in THF (2 mL) and a 1 M aq. NaOH solution (1 mL) and MeOH (1 mL) were added. The mixture was stirred for 2 h under air. More NaOH solution (0.5 mL) was added, and after 4 h the solution was diluted with Et_2O and washed with a saturated aq. NH_4Cl solution and H_2O. The organic layer was dried with Na_2SO_4 and evaporated under reduced pressure to yield a slightly yellow oil (54 mg, 0.281 mmol, 97%), which became solid after storage at 4 °C. Colorless solid. $[\alpha]_D$ = 1.7 ($CHCl_3$, *c* = 1.0); m.p. 39.0–39.9 °C.

(1*S*)-1-*tert*-Butyl-1-ethynyl-4,4-dimethylpent-2-yn-1-yl Pentafluorobenzoate [(*S*)-30]: Alcohol (*R*)-(–)-**27** was dissolved in THF and cooled to –78 °C. *n*BuLi (2.1 equiv.) was added and the mixture stirred for 15 min at –78 °C and 15 min at 20 °C. The solution was cooled to –78 °C, and ($i\text{Pr}_3$)SiCl (1.5 equiv.) was added. The mixture was stirred until TLC showed complete consumption of the starting material. Pentafluorobenzoyl chloride was added and the mixture stirred at 0 °C for 2 h. The reaction was quenched by the addition of a saturated aq. NH_4Cl solution. The aq. layer was extracted with Et_2O. The organic layer was washed with H_2O, dried with $MgSO_4$, filtered and the solvents evaporated. The desired product was obtained in 30–40% yield after purification by FC (Al_2O_3, activity III, hexane). R_f = 0.5 (Al_2O_3, hexane); $[\alpha]_D$ = –83. ^1H NMR (300 MHz, $CDCl_3$): δ = 1.22 (s, 9 H), 1.18 (s, 9 H), 1.08 (s, 21 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 11.4, 18.7, 25.0, 27.7, 30.6, 40.5, 74.5, 78.0, 88.3, 95.9, 102.3, 109.1, 136.4, 139.0, 141.7, 144.2, 146.6, 156.0 ppm. ^{19}F NMR (282 MHz, $CDCl_3$): δ = –161.1 (m), –139.1 (m), –150.1 (m) ppm. IR (film): $\tilde{\nu}$ = 2926, 2865, 1756, 1651, 1521, 1505, 1463, 1327, 1207, 1001, 955, 882 cm^{-1}. MS (EI): *m*/*z* (%) = 542 (21) $[M]^+$, 325 (29), 289 (40), 189 (100). $C_{29}H_{39}F_5O_2Si$ (542.70): calcd. C 64.18, H 7.24, F 17.50; found C 64.43, H 7.49, F 17.43.

(2*R*,*P*)-6,8-Bis(*tert*-butyl)-1,1,1-trifluoro-10-triisopropylsilyl-2-methoxy-2-phenyldeca-6,7-dien-4,9-diyn-3-one [(2*R*,*P*)-31]: Allene (*P*)-**15a** (19.5 mg, 55 μmol, 1.0 equiv., $[\alpha]_D$ = –82°) was dissolved in dry THF (0.5 mL) and hexane (0.5 mL) and cooled to –60 °C. *n*BuLi (36 μL of a 1.6 M solution in hexane, 58 μmol, 1.05 equiv.) was added, followed by Mosher acid chloride [(*R*)-MTPA-Cl, 20 μL, 107 μmol, 1.9 equiv.] after a few minutes. The solution was slowly warmed to 0 °C then to 20 °C. Cyclohexane was added, and the solution was washed twice with H_2O. The organic layer was dried with Na_2SO_4 and evaporated under reduced pressure. The resulting oil (quant.) was purified by flash-chromatography (SiO_2; cyclohexane/CH_2Cl_2, 10:0→10:1). Ketone **31** was obtained as an almost colorless oil (12 mg, 21 μmol, 39%). The ^1H NMR spectrum in C_6D_6 showed two distinct signals for the methoxy-groups of the 2 diastereoisomers. ^1H NMR (300 MHz, $CDCl_3$): δ = 0.966 and 0.969 (*s*, 9 H), 1.070 and 1.073 (*s*, 21 H), 1.10 (*s*, 9 H), 3.66–3.69 (*m*, 3 H), 7.38–7.41 (*m*, 3 H), 7.53–7.57 (*m*, 2 H) ppm. ^1H NMR (300 MHz, C_6D_6): δ = 0.938 and 0.942 (*s*, 9 H), 1.086 and 1.092 and 1.097 (*s*, 21 H), 1.11 (*s*, 9 H), 3.40–3.41 and 3.47–3.48 (*m*, 3 H), 7.00–7.04 (*m*, 3 H), 7.60–7.64 (*m*, 2 H) ppm. ^{13}C NMR (75 MHz, C_6D_6): δ = 11.8, 19.0, 28.8, 29.0, 35.9, 36.0, 55.8, 87.5, 89.7 and 89.8, 90.1, 97.4, 98.9 and 99.0, 101.88 and 101.94, 105.8 and 105.9, 124.2 (*q*, *J* = 287 Hz), 128.6, 129.6, 132.7, 179.9, 215.6 ppm. IR (film): $\tilde{\nu}$ = 2963, 2866, 2187, 1922 (w), 1683, 1461, 1273, 1168 (s), 1070 (s) cm^{-1}. MS (EI): *m*/*z* (%) = 573 (1) $[M + H]^+$, 563.94 (3), 529.28 (11) $[M – i\text{Pr}]^+$, 383.26 (51), 57.07 (100) $[t\text{Bu}]^+$. EI-HRMS: *m*/*z* calcd. for $C_{34}H_{48}O_2Si^+$: 573.3376, found 573.3314.

X-ray Analysis: The structures were solved by direct methods (SIR92)[22] and refined by full-matrix least-squares analysis (SHELXL-97),[23] using an isotropic extinction correction. All non H-atoms were refined anisotropically; H-atoms were refined isotropically, whereby H-positions are based on stereochemical considerations.

X-ray Crystal Structure of (±)-5b: Crystal data at 223(2) K for $C_{27}H_{28}O_2$, M_r = 384.49, monoclinic, space group *C* 2/*c* (no.15), $D_{calcd.}$ = 1.128 gcm^{-3}, *Z* = 4, *a* = 13.8290(3) Å, *b* = 6.5589(2) Å, *c* = 25.4813(7) Å, β = 101.615(1)°, *V* = 2263.90(11) $Å^3$; Bruker-Nonius Kappa-CCD diffractometer, Mo-K_α radiation, λ = 0.7107 Å, μ = 0.069 mm^{-1}. Approximate crystal dimensions 0.23 × 0.19 × 0.15 mm. Numbers of measured and unique reflections are 3675 and 2220, respectively (R_{int} = 0.017). Final *R*(*F*) = 0.051, w*R*(F^2) = 0.169 for 153 parameters and 1797 reflections with $I > 2\sigma(I)$ and $3.01 < \theta < 26.02°$ (corresponding *R* values based on all 2220 reflections are 0.064 and 0.187 respectively).

X-ray Crystal Structure of (P,M)-16a: Crystal data at 253(2) K for $C_{48}H_{78}Si_2$, M_r = 711.28, orthorhombic, space group *Pbca* (no.61), $D_{calcd.}$ = 0.940 gcm^{-3}, *Z* = 4, *a* = 9.2960(11) Å, *b* = 11.6725(12) Å, *c* = 46.3312(25) Å, *V* = 5027.3(9) $Å^3$; Bruker-Nonius Kappa-CCD diffractometer, Mo-K_α radiation, λ = 0.7107 Å, μ = 0.097 mm^{-1}. Approximate crystal dimensions 0.3 × 0.3 × 0.03 mm. Number of measured and unique reflections are 7684 and 4223, respectively (R_{int} = 0.022). Final *R*(*F*) = 0.047, w*R*(F^2) = 0.114 for 266 param-

eters and 3196 reflections with $I > 2\sigma(I)$ and $3.10 < \theta < 25.01°$ (corresponding R values based on all 4223 reflections are 0.068 and 0.124 respectively).

X-ray Crystal Structure of (*R*,*S*,*R*)-28: Crystal data at 120(2) K for $C_{23}H_{32}O_4$, M_r = 372.49, orthorhombic, space group $P2_12_12_1$ (no.19), $D_{calcd.}$ = 1.085 g cm^{-3}, Z = 4, a = 9.8869(13) Å, b = 12.6288(15) Å, c = 18.2670(15) Å, V = 2280.8(4) Å^3; Bruker-Nonius Kappa-CCD diffractometer, Mo-K_α radiation, λ = 0.7107 Å, μ = 0.073 mm^{-1}. A colorless crystal (linear dimensions *ca.* 0.2 × 0.18 × 0.16 mm) was obtained by evaporation of a hexane/pentane solution. Number of measured and unique reflections are 4390 and 2486, respectively (R_{int} = 0.030). Final $R(F)$ = 0.045, w$R(F^2)$ = 0.097 for 280 parameters and 2247 reflections with $I > 2\sigma(I)$ and $6.46 < \theta < 26.02°$ (corresponding R-values based on all 2486 reflections are 0.053 and 0.102, respectively).

CCDC-641333 (for **5b**), -641331 (for **16a**), and -641332 (for **28**) contain the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

Supporting Information (see also the footnote on the first page of this article): The synthesis and characterization of ynones **1a**–**d**, their precursors, and of compounds **2a**,**c**,**d**-(±) to **6a**,**c**,**d**, **8**-(±)-**13**, **24**, and **25**, a GPC chromatogram of the oligomers, partial NMR spectra of **28**, details on the HPLC experiments, and experimental details on the stereoselective synthesis.

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