100. Synthesis of Chiral 12-Phenyl(^{2}H)dodecanoic Acids: Useful Metabolic Probes for the Biosynthesis of 1-Alkenes from Fatty Acids

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The synthesis of chiral 12-phenyl(^{2}H)dodecanoic acids as metabolic probes for the evaluation of the stereochemical course of the biosynthesis of 1-alkenes from fatty acids in plants and insects is described. The diastereoisomeric (2*R*,3*R*)- or (2*S*,3*S*)-12-phenyl(2,3-$^2H_2$)dodecanoic acids **11** are obtained in high chemical and optical yield (> 97% e.e.) from the readily available (*E*)-12-phenyl(2,3-$^2H_2$)dodec-2-enoic acid (**10**) or (*E*)-12-phenyldodec-2-enoic acid (**10a**) by microbial reduction with wet packed cells of *Clostridium tyrobutyricum* in either ^2H_2O or H_2O buffer. (2*R*)- and (2*S*)-12-phenyl(2-^{2}H)dodecanoic acids **9** (> 97% e.e.) are accessible from the allylic alcohol **6** *via Sharpless* epoxidation with (+)-L- or (−)-D-diethyl tartrate. Synthetic routes to the (*E*)- and (*Z*)-11-phenyl(1-^{2}H) undec-1-enes **16** and **16a** as reference compounds are also included.

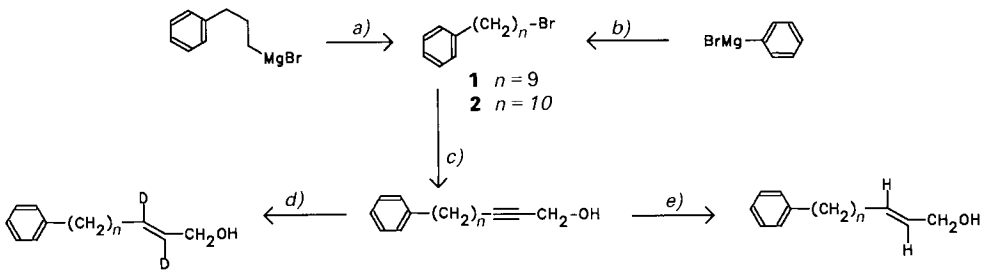
Introduction. – The vinyl group is a widespread structural element of numerous natural products like, *e.g.*, porphyrins, terpenoids, simple olefins, pheromones, or polyacetylenes. Notwithstanding its nearly ubiquitous presence in all kinds of natural products, surprisingly little is known about is biosynthesis. In spite of detailed studies in the field of porphyrins [1] and experimental evidence for carboxylic acids being precursors in the case of the polyacetylenes [2] and olefins, there exists no profound mechanistic study on the stereochemical course of the biosynthesis of 1-alkenes from fatty-acid precursors.

Recently, we have shown, that all previous biosynthetic hypotheses proposing paths *via* intermediates of the β-oxidation cycle are incorrect; instead of the postulated 3-hydroxy-, 3-oxo- or 2-alkenoic acids, the biosynthesis of 1-alkenes requires the nonfunctionalized free fatty acids as precursors [3]. These results were obtained with germinating seeds of *Carthamus tinctorius* (dyers thistle) which produce high amounts of vinylic C_{15}- and C_{17} polyolefins. As precursors, we used either ^{2}H-labelled linolenic acids or, with benefit, 12-phenyl(^{2}H)dodecanoic acids as artificial substitutes for the natural substrates. Such aromatic acids are rapidly incorporated and smoothly converted into the corresponding 11-phenyl(^{2}H)undec-1-enes which provide excellent mass-spectroscopic properties for their unambiguous identification among other hydrocarbons. Since 12-phenyldodecanoic acids are resistant towards autooxidation, readily available by synthesis, and effective substitutes for linolenic – or linoleic acid, they were further used as metabolic probes to unravel the stereochemical course of the biosynthesis of 1-alkenes from fatty acids in the plant and animal kingdom.

We now report an efficient and highly enantioselective synthesis of chiral 12-phenyl-(^{2}H)dodecanoic acids which may serve as convenient metabolic probes of broad applicability to follow the stereochemical course of enzymatic activities at the polar head of poly-unsaturated C_{18} fatty acids.

^{2}H-Substituted 12-Phenyldodecanoic Acids. – The preparation of the required 12-phenyl- or 13-phenyl-alk-2-en-1-ols **5**, **5a**, and **6** is accomplished through the sequence of reactions outlined in *Scheme 1*. Coupling of (3-phenylpropyl)magnesium bromide or phenylmagnesium bromide with either 1,6-dibromohexane or 1,10-dibromodecane according to [4] gives the terminal (bromoalkyl)benzenes **1** and **2** along with some 1,12-diphenyldodecane or 1,10-diphenyldecane, respectively. The alkynols **3** and **4** are then obtained in high yields on treatment of **1** or **2** with {3-[(tetrahydropyran-2-yl)oxy]prop-1-ynyl}lithium and subsequent deblocking of the alcohol moiety.

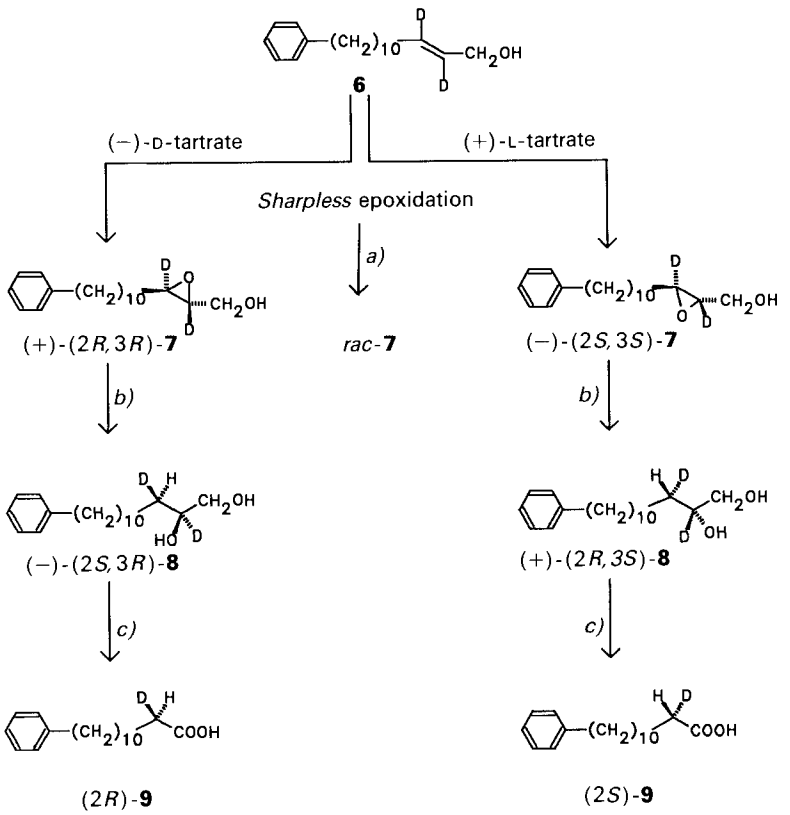
Scheme 1



a) $Br(CH_2)_6Br$, Li_2CuCl_4. *b*) $Br(CH_2)_{10}Br$, Li_2CuCl_4. *c*) 1. Li–C≡C–CH_2O–THP, 2. MeOH/Py·TsOH. *d*) 1. $LiAl^2H_4$, 2. ^2H_2O. *e*) 1. $LiAlH_4$, 2. H_2O.

Due to lacking regioselectivity, the conventional introduction of a ^{2}H-label *via* $LiAlH_4$ reduction of the alkynols **3** and **4** followed by hydrolysis with ^2H_2O is not satisfactory (75% of ^{2}H at C(3) and 25% of ^{2}H at C(2)). However, simultaneous labelling of C(2) and C(3) of the alkynols **3** and **4** using $LiAl^2H_4$ for reduction and ^2H_2O for hydrolysis is readily achieved ($\geq$ 99% ^{2}H at both C-atoms of **5** and **6**) and circumvents the necessity of regiospecific labelling. Then, the resulting (*E*)-alkenol **6** is subjected to a catalytical *Sharpless* epoxidation [5] with either (+)-L or (−)-D-diethyl tartrate as chiral ligands yielding the two diastereoisomeric epoxyalcohols (2*R*,3*R*)- and (2*S*,3*S*)-**7** *(Scheme 2)* in $\geq$ 97% enantiomeric excess (determined by ^{1}H-NMR analysis of the corresponding *Mosher* esters [6]). After addition of Ti(i-PrO)$_4$ to (2*R*,3*R*)- or (2*S*,3*S*)-**7**, the resulting alkoxytitanates are reduced with $LiBH_4$ [7] to the 1,2-diols (2*S*,3*R*)- and (2*R*,3*S*)-**8** which can be oxidatively cleaved to the epimeric ^{2}H-substituted acids (2*R*)- and (2*S*)-**9**, respectively. Final ^{1}H-NMR analysis of their mandelate diesters indicate both acids to be at least $\geq$ 97% enantiomerically pure (*vide infra*). Thus, both steps (reduction and oxidation) proceed virtually without racemization.

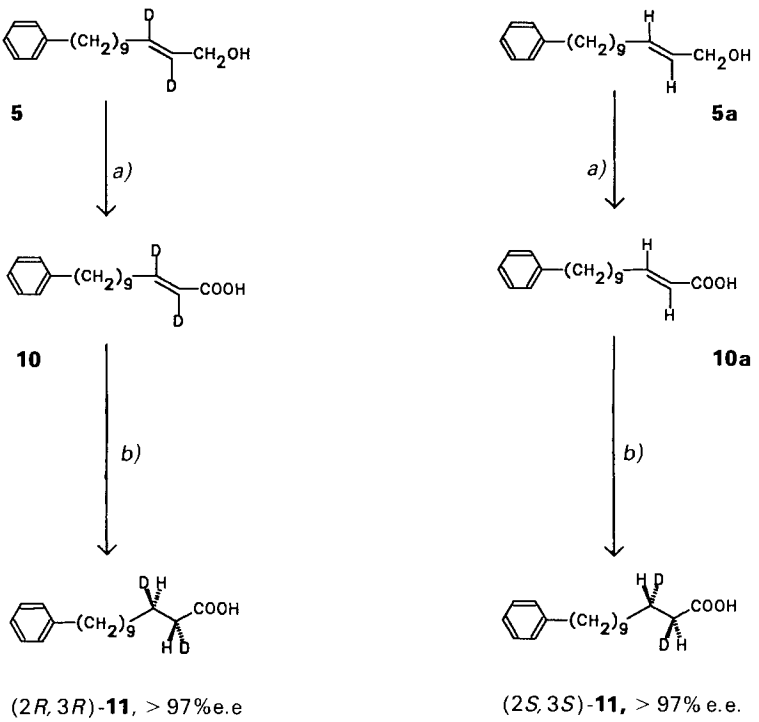
Scheme 2



a) 3-$ClC_6H_4CO_3H$. *b*) 1. $Ti(i\text{-}PrO)_4$, 2. $LiBH_4$. *c*) $RuCl_3 \cdot 3H_2O/NaIO_4$.

For the enantioselective synthesis of chiral 12-phenyl(2,3-$^2H_2$)dodecanoic acids, microbial reduction of 2-alkenoates like **10** or **10a** is a direct and attractive approach [8]. For this purpose, the (*E*)-alcohols **5** or **5a** are first oxidized to an aldehyde (MnO_2) and then to the required acids **10** and **10a** by $NaClO_2$/α-amylene (= 2-methylbut-2-ene) under neutral conditions [9]. This two-step sequence is superior to the usual oxidation procedures ($Cr(VI)/H^+$; $Ag(I)/OH^-$ *etc.*), since the latter give less pure products, mainly contaminated by the nonseparable 10-phenyldecanoic acid (10–25%) as a result of an oxidative attack on the double bond. Although the acids **10** and **10a** are largly insoluble in H_2O or aq. buffer systems, suspensions of substrate **10** in a 0.1M phosphate buffer, pH 7.0, are rapidly reduced by thawed wet packed cells of *Clostridium tyrobutyricum* (strain C. La 1, DSM-No. 1460, *Scheme 3*). The reduction cleanly ceases after the uptake of 1 equiv. of $^1H_2$ gas. Extractive workup of the heterogeneous mixture (Et_2O) gives the (2*R*,3*R*)-acid **11** in 61% yield, along with *ca.* 2–3% of the starting material. If the (^{1}H)acid **10a** is reduced by the same method in a ^2H_2O buffer and with $^1H_2$ gas, the required enantiomer (2*S*,3*S*)-**11** is obtained in 67% overall yield.

Scheme 3



a) 1. MnO_2, 2. $NaClO_2$/α-amylene, NaH_2PO_4 buffer, pH 7. *b*) H_2O, *Clostridium tyrobutyricum* (C. La 1).

Product Chirality by the Mandelate-Diester Approach. – To determine the enantiomeric excess (e.e.) of the above 12-phenyl(^{2}H)dodecanoic acids **9** and **11**, they are converted into their mandelate diesters and analyzed by ^{1}H-NMR *(Fig.)*. To provide highest accuracy for the integration of the relative peak areas of the diastereotopic proton(s) at C(2), the vicinal coupling with H–C(3) is eliminated by irradiation at 1.60 ppm (H–C(3)). The mandelates of the racemic acids *rac*-**9** and *rac*-**11** display two *s* of equal intensity at 2.40 and 2.455 ppm, while the mandelates of chiral acids comprise only one signal, located at 2.455 ppm (2*S*) or 2.40 ppm (2*R*), respectively. The spectra provide no evidence for the presence of the opposite enantiomer. Thus, within the limits of error of the ^{1}H-NMR method, the enantiomeric excess of all chiral (^{2}H)acids is $\geqslant 97\%$. The downfield appearance of the proton at C(2) of the mandelates of (2*S*)-(2-^{2}H)acids is in agreement with the examples reported by *Parker* [10]. It is also in agreement with the known site specificity of the enoate reductase of *Clostridium tyrobutyricum* [11] or the stereochemical course of the *Sharpless* epoxidation.

To visualize the enantiospecificity of the microbial reduction with respect to the proton at C(3), the acid (2*R*,3*R*)-**11** is esterified (CH_2N_2) and treated with PhLi, and the resulting tertiary alcohol eliminated under acidic conditions to yield the 1,1,12-triphenyldodec-1-ene **12** *(Scheme 4)*. After oxidative cleavage of the double bond with Ru(VIII) [12], the resulting (2*R*)-11-phenyl(^{2}H)undecanoic acid ((2*R*)-**13**) is converted into the

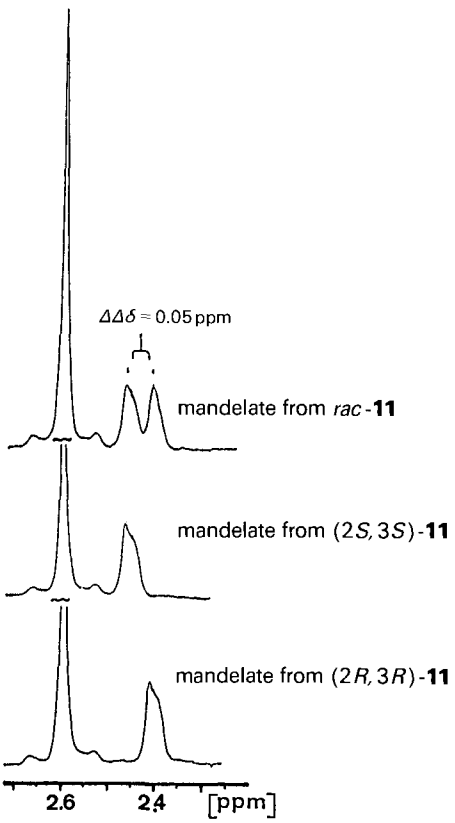
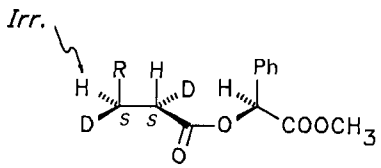
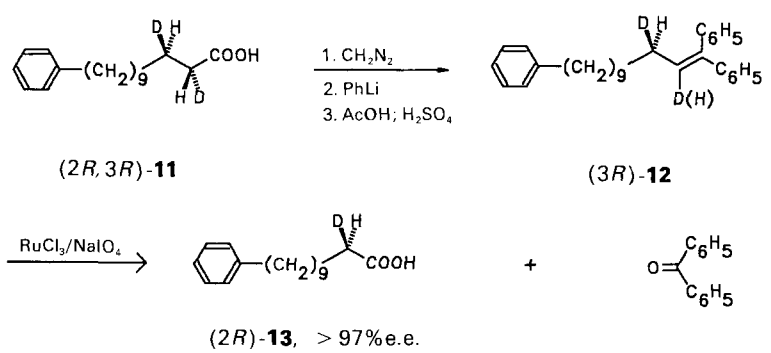


Figure. *250-MHz ^{1}H-NMR spectra of mandelate diesters from* rac-**11** *(2S,3S)-***11**, *and (2R,3R)-***11**. Spectra were recorded in $CDCl_3$ with irradiation at 1.60 ppm of the adjacent H–C(3). The mandelates from (2*S*)-**9** and (2*R*)-**9** gave the same signals, respectively.



mandelate diester and analyzed as before. Again, no indication for the presence of a second enantiomer is found. Thus, the reduction of **10** and **10a** by *Clostridium tyrobutyricum* had occurred with $\geq 97\%$ e.e. with respect to both centers, as has been previously shown with other substrates [11].

Scheme 4

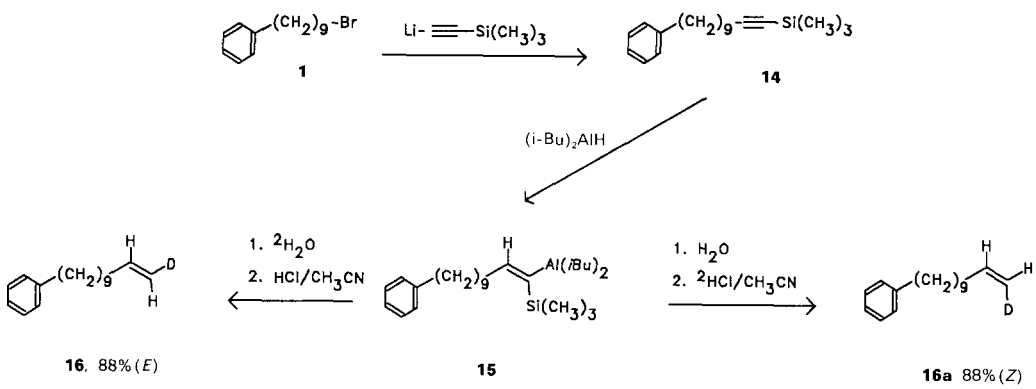


(2*R*,3*R*)-**11** (3*R*)-**12**

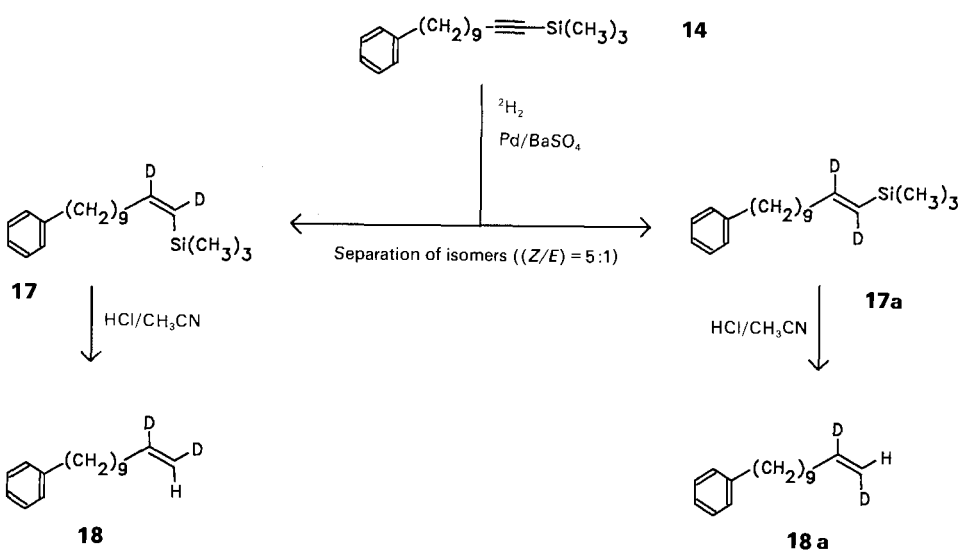
(2*R*)-**13**, > 97% e.e.

(*E*)- and (*Z*)-11-Phenyl(²H)undec-1-enes. – To study the stereochemical course of the biosynthesis of 1-alkenes in plants with the 12-phenyl(²H)dodecanoic acids as metabolic probes, the corresponding (*E*)- or (*Z*)-11-phenyl(1-²H)undec-1-enes are required as configurationally pure references. These compounds are readily available from **1** by substitution of the bromide by 1-lithio-2-(trimethylsilyl)acetylene. Next, the (trimethylsilyl)-alkyne **14** is reacted with *DIBAL-H* (diisobutylaluminium hydride) [13]. If the resulting organoaluminium intermediate **15** is first hydrolyzed with ^2H_2O, followed by removal of the silyl group with H^+/CH_3CN, the (*E*)-11-phenyl(1-²H)undec-1-ene (**16**; 88% (*E*)) is obtained. Reversal of the sequence (1. H_2O, 2. ^2HCl) leads to the (*Z*)-isomer **16a** (88% (*Z*), *Scheme 5*).

Scheme 5



Scheme 6



The two isomeric 11-phenyl(1,2-$^2H_2$)undec-1-enes **18** and **18a** are synthesized from **14** *via* hydrogenation with $^2H_2$ gas and *Lindlar*'s catalyst *(Scheme 6)*. Although this reduction is expected to give a high amount of the (*Z*)-(trimethylsilyl)alkene **17**, we have observed rapid isomerization of the original compound after *ca.* 50% conversion of the starting material. Obviously, the unfavorable steric interaction between the bulky trimethylsilyl group and the aliphatic side chain leads to rotation around the terminal C–C σ-bond after labilization of the C=C bond at the nobel metal catalyst. After complete conversion of **14**, the product consists of 85% (*Z*)- and 15% (*E*)-(trimethylsilyl)alkenes **17** and **17a**. Both are readily separated by medium-pressure liquid chromatography (MPLC) on silver-impregnated silica gel (10% $AgNO_3$). Hydrolysis with HCl/CH_3CN provides the configurationally pure (*Z*)- and (*E*)-11-phenyl(1,2-$^2H_2$)undec-1-enes (**18** and **18a**, respectively). In contrast to the (*E*)- and (*Z*)-(1-^2H)olefines **16** and **16a**, **18** or **18a** display virtually identical IR- and ^1H-NMR spectra and can not be used to follow the stereochemical course of the biosynthesis of 1-alkenes from fatty acids.

Administration experiments with the 12-phenyl(^2H)dodecanoic acids **9** and **11** and germinating seeds of *Carthamus tinctorius* were already successful. The experiments establish a high preference of the plant's enzyme(s) for the *pro-S* H-atom at C(3) of the precursor acid. The overall stereochemical course is consistent with an *anti*-elimination of the H-atom and the carboxyl group. The detailed study will be published elsewhere [15].

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Experimental Part

General. Reactions were performed under Ar. Solvents and reagents were purified and dried prior to use. Anh. $MgSO_4$ was used for drying operations. Solns. were usually concentrated by flash evaporation under reduced pressure. Anal. TLC: 20 × 20 cm TLC plates, SiO_2 *60* F_{254}, layer thickness 0.2 mm (*E. Merck & Co.*, Darmstadt, FRG). Anal. GLC: *Carlo-Erba* gas chromatograph, *HRGC 5300, Mega* series, equipped with fused silica capillaries, *SE 30* (10 m × 0.31 mm); carrier gas, H_2 at 30 cm/s. Polarimetry: *Perkin-Elmer 141*, optical rotations at 21°. IR (cm^{-1}): *Perkin Elmer 882* IR spectrophotometer. ^1H-NMR (250 or 400 MHz, $CDCl_3$, TMS as internal standard): *Bruker Cryospec WM 250* and *Bruker WM 400*. MS (*m/z*): *Finnigan 4510* GLC/MS system and *Finnigan ITD 800* combined with a *Carlo Erba* gas chromatograph, model *Vega*; carrier gas, He at 30 cm/s.

(9-Bromononyl)benzene (**1**). At 0°, (3-phenylpropyl)magnesium bromide (0.45 ml) in THF (250 ml) was slowly added to a well stirred soln. of 1,6-dibromohexane (0.40 mol) and Li_2CuCl_4 (4.0 mmol) in THF (200 ml). During addition, the temp. was kept below 10° to avoid the formation of larger amounts of 1,12-diphenyldodecane. Stirring was continued over night at r.t., and 300 ml of sat. NH_4Cl soln. were added. Following extraction (3 × 100 ml Et_2O), washing (sat. NaCl soln., 2N HCl, 10% Na_2CO_3 soln., and H_2O), drying, and evaporation the crude product was purified by distillation: 49.8 g (44%). B.p. 115°/0.2 Torr. IR: 3090*w*, 3070*w*, 3030*m*, 3000*w*, 2930*s*, 2860*s*, 1605*m*, 1500*s*, 1470*s*, 1455*s*, 1030*w*, 740*s*, 700*s*. ^1H-NMR: 7.21 (*m*, C_6H_5); 3.38 (*t*, CH_2Br); 2.60 (*t*, $C_6H_5CH_2$); 1.82 (*quint.*, CH_2CH_2Br); 1.61 (br. *m*, $C_6H_5CH_2CH_2$); 1.43–1.23 (*m*, 5 CH_2). MS: 284, 282 (8, 8, $M^{+\cdot}$), 238 (2), 147 (3), 133 (8), 117 (4), 104 (10), 92 (82), 91 (100), 78 (4), 65 (16), 55 (10), 41 (25). HR-MS: 282.0994, 284.0925 ($C_{15}H_{23}Br$, $M^{+\cdot}$, calc. 282.0972, 284.0954).

(10-Bromodecyl)benzene (**2**). Prepared from phenylmagnesium bromide (0.45 mol) and 1,10-dibromodecane (0.40 mol) as described for **1**: 48.0 g (44%). B.p. 119°/0.07 Torr. IR: identical with that of **1**. ^1H-NMR: identical with that of **1**, except: 1.43–1.23 (br. *s*, 6 CH_2). MS: 298, 296 (12, 12, $M^{+\cdot}$), 254 (0.5), 161 (1), 147 (2), 133 (10), 119 (3), 104 (8), 92 (92), 91 (100), 77 (5), 65 (14), 55 (14), 41 (28). HR-MS: 296.1160, 298.1136 ($C_{16}H_{25}Br$, $M^{+\cdot}$ calc. 296.1130, 298.1110).

12-Phenyldodec-2-yn-1-ol (**3**). A soln. of 3-[(tetrahydropyran-2-yl)oxy]prop-1-yne (27.4 g, 0.196 mol) in dry THF (220 ml) at r.t. was treated dropwise with BuLi (0.21 mol; 86.2 ml of 2.5M soln. in hexane). After stirring for 15 min, hexamethylphosphoric triamide (HMPA) (15 ml) was added. Then, a soln. of **1** (0.151 mol) in HMPA (10 ml) was added in 3 portions at which the temp. raised to *ca.* 40°. Stirring was continued over night, followed by addition of H_2O (100 ml). The mixture was extracted with Et_2O (3 × 150 ml), and the org. layers were washed with H_2O, dried, and evaporated. The crude product was then dissolved in MeOH (500 ml) containing pyridinium *p*-toluenesulfonate (0.5 g) and refluxed for 30 min to remove the protecting group. After addition of pyridine (7 ml) and cooling, the solvent was removed *i.v.* at 35°. The dark residue was dissolved in Et_2O (200 ml) and washed with 2N HCl (2 × 100 ml). After drying and evaporation of the solvent, the product was purified by CC on silica gel using hexane/Et_2O 8:2 (*v*/*v*): 26.7 g (68%). IR: 3360*s* (br.), 3090*w*, 3070*w*, 3030*m*, 3000*w*, 2935*s*, 2860*s*, 2300*w*, 2290*w*, 2230*w*, 1605*m*, 1495*s*, 1465*s*, 1455*s*, 1140*s*, 1020*s*, 750*s*, 700*s*. ^{1}H-NMR: 7.21 (*m*, C_6H_5); 4.25 (*t*, CH_2OH); 2.60 (*t*, $C_6H_5CH_2$); 2.20 (*t*, $CH_2C{\equiv}C$); 1.63 (br. *m*, $C_6H_5CH_2CH_2$, OH); 1.51 (*m*, $CH_2CH_2C{\equiv}C$); 1.40–1.25 (br. *m*, 5 CH_2). MS: 258 (2, $M^{+\cdot}$), 157 (2), 143 (7), 130 (11), 117 (12), 104 (23), 91 (100), 79 (21), 70 (31), 65 (23), 55 (21), 41 (31), 39 (34). HR-MS: 258.1988 ($C_{18}H_{26}O$, $M^{+\cdot}$, calc. 258.1977).

13-Phenyltridec-2-yn-1-ol (**4**). Prepared from **2** (0.151 mol) as described for **3**: 28.5 g (72%). IR: identical with that of **3**. ^{1}H-NMR: identical with that of **3**, except: 1.40–1.25 (*m*, 6 CH_2). MS: 272 (0.5, $M^{+\cdot}$), 254 (0.4), 197 (0.4), 183 (1.3), 169 (2), 155 (3), 143 (7), 131 (14), 117 (14), 104 (13), 91 (100), 79 (18), 70 (63), 55 (20), 41 (29), 39 (21). HR-MS: 272.2168 ($C_{19}H_{28}O$, $M^{+\cdot}$, calc. 272.2133).

Phenylalk-2-en-1-ols: General Procedure. A soln. of ω-phenylalkynol **3** or **4** (147.0 mmol) in dry THF (150 ml) was added slowly with stirring at r.t. to a suspension of $LiAlH_4$ or $LiAl^2H_4$ (147.0 mmol) in THF (250 ml). After brief reflux for 30 min, the mixture was chilled and hydrolyzed by slow addition of sufficient H_2O or ^2H_2O (99.7% ^2H). In the case of ^2H-labelling, stirring was continued for 30 min prior to addition of ^2HCl. Further 150 ml of H_2O were added, and the products were extracted with Et_2O (3 × 100 ml). After drying and evaporation, the residue was chromatographed on silica gel with hexane/Et_2O 8:2.

(E)-12-Phenyl(2,3-$^2H_2$)dodec-2-en-1-ol (**5**). From **3** and $LiAl^2H_4$ and ^2H_2O in 87% yield (> 99% ^2H). IR: 3335 (br.), 3090*w*, 3070*w*, 3030*m*, 2930*s*, 2860*s*, 2220*w*, 1640*w*, 1605*w*, 1495*m*, 1455*m*, 1080*m*, 910 (br.), 745*m*, 720*m*, 700*s*. ^{1}H-NMR: 7.21 (*m*, C_6H_5); 4.08 (*d*, CH_2OH); 2.60 (*t*, $C_6H_5CH_2$); 2.03 (*t*, $CH_2CD{=}CD$); 1.52–1.61(br. *m*, OH, $C_6H_5CH_2CH_2$); 1.42–1.22 (br. *m*, 6 CH_2). MS: 244 (4, $M^{+\cdot} - H_2O$), 144 (5), 131 (20), 117 (16), 104 (55), 91 (100), 75 (12), 70 (19), 59 (21), 41 (28). HR-MS: 244.2152 ($C_{18}H_{26}{}^2H_2O$, $M^{+\cdot} - H_2O$, calc. 244.2158).

(E)-12-Phenyldodec-2-en-1-ol (**5a**). From **3** $LiAlH_4$ in 83% yield. IR: 3350*m* (br.), 3090*w*, 3065*w*, 3030*m*, 3000*w*, 2930*s*, 2860*s*, 1605*w*, 1500*m*, 1460*m*, 1465*m*, 1090*m*, 1005*m*, 970*s*, 745*m*, 700*s*. ^{1}H-NMR: 7.21 (*m*, C_6H_5); 5.66 (*m*, $CH{=}CHCH_2OH$); 4.08 (*t*, CH_2OH); 2.60 (*t*, $C_6H_5CH_2$); 2.03 (*quint.*, $CH_2CH{=}CH$); 1.61 (*m*, $C_6H_5CH_2CH_2$, OH); 1.41–1.25 (br. *m*, 6 CH_2). MS: 242 (4, $M^{+\cdot} - H_2O$), 199 (3), 143 (4), 129 (20), 117 (18), 104 (62), 91 (100), 81 (15), 70 (12), 67 (23), 55 (31), 41 (48). HR-MS: 242.2018 ($C_{18}H_{28}O$, $M^{+\cdot} - H_2O$, calc. 242.2035).

(E)-13-Phenyl(2,3-$^2H_2$)tridec-2-en-1-ol (**6**). From **4** and $LiAl^2H_4$ and ^2H_2O in 91% yield (> 99% ^2H). M.p. 29°. IR: identical with that of **5**. ^{1}H-NMR: identical with that of **5**, except: 1.42–1.22 (br. *m*, 7 CH_2). MS: 258 (8, $M^{+\cdot} - H_2O$), 199 (1), 186 (1), 157 (2), 144 (4), 131 (18), 117 (17), 104 (71), 91 (100), 83 (7), 65 (13), 59 (25), 55 (17), 41 (24). HR-MS: 258.2327 ($C_{19}H_{28}{}^2H_2O$, $M^{+\cdot} - H_2O$, calc. 258.2308).

(+)-(2R,3R)-trans-2,3-Epoxy-13-phenyl(2,3-$^2H_2$)tridecan-1-ol ((2*R*,3*R*)-**7**). To a suspension of molecular sieves (4 Å 1.5 g) and (−)-D-diethyl tartrate (0.62 g, 2.5 mmol) in dry CH_2Cl_2 (175 ml), Ti(i-PrO)$_4$ (0.75 ml, 2.5 mmol) was added with stirring at −22°. After 5 min *t*-BuOOH (33.3 ml, 0.1 mol; 3M in 2,2,4-trimethylpentane) was added within 5 min, and the catalyst was 'aged' for 30 min. Then, a soln. of **6** (13.8 g, 50.0 mmol) in dry CH_2Cl_2 (25 ml) was added within 20 min, while the temp. was kept at −22°. After 150 min, the mixture was allowed to come to 0° and poured into a chilled soln. of $FeSO_4 \cdot 7H_2O$ (16.5 g, 60.0 mmol) and tartaric acid (5.0 g; 30 mmol) in H_2O (100 ml). Stirring was continued for 5 min, and the two phases were allowed to separate. The aq. phase was extracted with Et_2O (2 × 30 ml), and the combined org. layers were treated with 5.0 mol of a soln. of NaOH (30%) in sat. NaCl (1:1, *v*/*v*) with stirring for 30 min at 0°. H_2O (50 ml) was added and the product extracted with CH_2Cl_2 (2 × 50 ml). After drying and evaporation, the residue was purified by CC on silica gel (hexane/Et_2O 6:4) and crystallization from 60 ml of pentane/Et_2O 1:1 at −20°: 8.7 g (60%) of colorless crystals. M.p. 39°. $[\alpha]_D = 19.3$ (CH_2Cl_2, $c = 5.00$). IR: 3350 (br.), 3090*w*, 3070*w*, 3030*w*, 2920*s*, 2850*s*, 2200*w*, 1500*m*, 1465*m*, 1450*m*, 1080*m*, 1060*m*, 1050*m*, 955*m*, 905*m*, 815*m*, 700*m*. ^{1}H-NMR: 7.21 (*m*, C_6H_5); 3.91 (*d*, 1H, CH_2OH); 3.62 (*d*, 1 H, CH_2OH); 2.60 (t, $C_6H_5CH_2$); 2.05 (br. *s*, OH); 1.68–1.50 (*m*, $C_6H_5CH_2CH_2$, CH_2CDO); 1.45–1.20 (br. *m*, 7CH_2). MS: 274 (2, $M^{+\cdot} - H_2O$), 253 (3), 229 (2), 207 (8), 193 (2), 171 (2), 147 (3), 131 (8), 117 (10), 104 (40), 92 (43), 91 (100), 75 (7), 65 (18), 55 (17), 41 (36). Anal. calc. for $C_{19}H_{29}{}^2H_2O_2$ (293.44): calc. C 78.03, H 11.02; found: C 78.00, H 10.92.

*(−)-(2S,3S)-*trans*-2,3-Epoxy-13-phenyl(2,3-$^2H_2$)tridecan-1-ol* ((2*S*,3*S*)-**7**). Prepared from **6** (50.0 mmol) and (+)-L-diethyl tartrate as described for (2*R*,3*R*)-**7**. Yield: 9.5 g (65%). M.p. 39°. $[\alpha]_D = -19.15$ (CH_2Cl_2, $c = 4.99$). Spectroscopic data: identical with that of (2*R*,3*R*)-**7**.

rac-trans-*2,3-Epoxy-13-phenyl(2,3-$^2H_2$)tridecan-1-ol* (*rac*-**7**). Prepared from **6** (6.15 g, 22.3 mmol) and 3-chloroperbenzoic acid (5.0 g, 29.0 mmol) in CH_2Cl_2 (150 ml) at 0°. After 60 min, the soln. was washed with sat. $NaHCO_3$ soln. (2 × 100 ml) and H_2O (2 × 100 ml), dried, and evaporated. Purification over silica gel with hexane/Et_2O 6:4 afforded 5.54 g (85%) of *rac*-**7**. Spectroscopic data: identical with (2*R*,3*R*)-**7**.

Mosher *Esters of the 2,3-Epoxyalcohols: General Procedure* [6]. A soln. of epoxyalcohol (73.0 mg, 0.25 mmol) and (+)-(*S*)-2-methoxy-2-phenyl-2-(trifluoromethyl)acetyl chloride (87.5 mg, 0.35 mmol) in dry pyridine (750 µl) and CCl_4 (750 µl) was stirred for 60 min at r.t. Then, 3-(dimethylamino)propylamine (50.0 mg, 0.5 mmol) was added and stirring continued for 5 min. Then, Et_2O (20 ml) was added and the org. layer washed with 2N HCl (10 ml), sat. Na_2CO_3 soln. (10 ml), and brine (10 ml). After drying and evaporation, the product was purified by CC on silica gel using hexane/Et_2O 8:2 (TLC control (same solvent)): 93.0 mg (73%). IR (identical for all *Mosher* esters): 3070*w*, 3030*w*, 2930*s*, 2860*s*, 2250*w*, 1750*s*, 1600*w*, 1500*m*, 1450*m*, 1275*s*, 1250*s*, 1185*s*, 1120*m*, 1080*m*, 1020*w*, 910*m*, 760*m*, 735*s*, 720*s*, 700*m*. ^{1}H-NMR (*Mosher* ester of *rac*-**7**): 7.47 (*m*, $C_6H_5CCF_3$); 7.21 (*m*, $C_6H_5CH_2$); 4.57, 4.52 (2*d*, $J = 11.5$, 1 H, CH_2O); 4.23, 4.18 (2 *d*, $J = 11.5$, 1 H, CH_2O); 3.56 (*s*, CH_3O); 2.60 (*t*, $C_6H_5CH_2$); 1.65–1.50 (*m*, $C_6H_5CH_2CH_2$, CH_2CHOC); 1.42–1.22 (br. *s*, 7 CH_2). *Mosher* ester of (2*S*,3*S*)-**7**: 4.53 (*d*, 1 H); 4.23 (*d*, 1 H); no evidence for (2*R*,3*R*)-**7**. *Mosher* ester of (2*R*,3*R*)-**7**: 4.57 (*d*, 1 H); 4.21 (*d*, 1 H), no evidence for (2*S*,3*S*)-**7**. MS (identical for all *Mosher* esters): 508 (1, M^+), 256 (1.5), 246 (1.2), 189 (81), 165 (1), 152 (1), 139 (3), 131 (18), 117 (13), 105 (21), 104 (22), 96 (5), 92 (20), 91 (100), 77 (4), 69 (11), 55 (15), 41 (15).

(−)-(2S,3R)-13-Phenyl(2,3-$^2H_2$)tridecane-1,2-diol ((2*S*,3*R*)-**8**). A soln. of (2*R*,3*R*)-**7** (6.0 g, 20.5 mmol) in dry benzene (200 ml) was treated at r.t. with Ti(i-PrO)$_4$ (11.1 g, 39.0 mmol). Stirring was continued for 5 min at r.t., followed by cooling to 10° and addition of $LiBH_4$ (1.7 g, 78.0 mmol) in three portions. The soln. was allowed to come to r.t., and after 5 h the mixture was quenched by addition of cold 5% H_2SO_4 soln. (250 ml). When 2 clear phases had formed, the aq. layer was extracted with Et_2O, and the combined org. extracts were washed with H_2O, dried, and evaporated. The product was purified by recrystallization from Et_2O (150 ml) at −20°: 3.3 g (55%) of colorless crystals. M.p. 52°. $[\alpha]_D = -0.31$ (CH_2Cl_2, $c = 5.13$). IR: 3400*s* (br.), 3090*w*, 3070*w*, 3035*w*, 2920*s*, 2850*s*, 2150*w*, 2080*w*, 1605*w*, 1500*m*, 1470*s*, 1450*m*, 1155*m*, 950*m*, 845*m*, 740*m*, 720*m*, 695*m*. ^{1}H-NMR: 7.21 (*m*, C_6H_5); 3.65 (*d*, 1 H, CH_2OH); 3.42 (*d*, 1 H, CH_2OH); 2.60 (*t*, $C_6H_5CH_2$); 2.33 (br. *s*, 2 OH); 1.61 (*quint.*, $C_6H_5CH_2CH_2$); 1.48–1.20 (br. *m*, H–C(3), 8 CH_2). MS: 294 (27, M^+), 148 (2), 147 (2), 133 (6), 117 (3), 104 (8), 92 (62), 91 (100), 77 (3), 65 (12), 55 (3), 41 (8). Anal. calc. for $C_{19}H_{30}{}^2H_2O_2$ (294.45): C 77.55, H 11.63; found: C 77.70, H 11.43.

(+)-(2R,3S)-13-Phenyl(2,3-$^2H_2$)tridecane-1,2-diol ((2*R*,3*S*)-**8**). From (2*S*,3*S*)-**7** (20.5 mmol) as described for (2*S*,3*R*)-**8**: 4.0 g (66%). $[\alpha]_D = 0.31$ (CH_2Cl_2, $c = 5.13$). Spectroscopic data: identical with that of (2*S*,3*R*)-**8**.

rac-*13-Phenyl(2,3-$^2H_2$)tridecane-1,2-diol* (*rac*-**8**). From *rac*-**7** (3.0 g, 10.3 mmol) as described for (2*S*, 3*R*)-**8**: 1.8g (59%). Spectroscopic data: identical with that of (2*S*,3*R*)-**8**.

(2R)-12-Phenyl(2-^2H)dodecanoic Acid ((2*R*)-**9**). To a soln. of 2.2 g (7.48 mmol) of (2*S*,3*R*)-**8** in CCl_4 (15 ml), CH_3CN (15 ml), and H_2O (22.4 ml), $NaIO_4$ (6.65 g, 31.4 mmol) and $RuCl_3 \cdot 3\,H_2O$ (43.0 mg, 0.16 mmol) are added with stirring at r.t. After 60 min H_2O (50 ml) and CH_2Cl_2 (50 ml) were added, and the aq. layer was extracted with additional portions of CH_2Cl_2 (3 × 20 ml). Drying and evaporation afforded crude (2*R*)-**9**. Chromatography on silica gel with hexane/Et_2O 7:3 removed admixtures of the catalyst and yielded, after recrystallization from heptane at −20°, 1.2 g (58%) of colorless crystals. M.p. 59°. IR: 3340*m* (br.), 3090*w*, 3070*w*, 3030*m*, 2920*s*, 2850*s*, 1700*s*, 1470*m*, 1460*m*, 1450*m*, 1420*m*, 1315*m*, 1290*m*, 950*m-w*, 940*m*, 745*s*, 700*s*. ^{1}H-NMR: 7.22 (*m*, C_6H_5); 2.60 (*t*, $C_6H_5CH_2$); 3.32 (*t*, 1 H, CHD); 1.61 (br. *quint.*, $C_6H_5CH_2CH_2$ CH_2CDH); 1.40–1.20 (br. *s*, 7 CH_2). MS (methyl ester): 291 (5, M^+), 259 (32), 241 (2), 200 (3), 185 (1), 168 (11), 150 (7), 131 (7), 117 (9), 104 (26), 92 (36), 91 (100), 75 (18), 65 (16), 55 (15), 41 (24). Anal. calc. for $C_{18}H_{27}{}^2H_1O_2$ (278.65): C 77.94, H 10.53; found: C 78.05, H 10.43.

(2S)-12-Phenyl(2-^2H)dodecanoic Acid ((2*S*)-**9**). Prepared from (2*R*,3*S*)-**8** as described for (2*R*)-**9** in 53% yield. Spectroscopic data: identical with that of (2*R*)-**9**.

rac-*12-Phenyl(2-^2H)dodecanoic Acid* (*rac*-**9**). Prepared from *rac*-**8** as described for (2*R*)-**9** in 48% yield. Spectroscopic data: identical with that of (2*R*)-**9**.

(E)-12-Phenyldodec-2-enoic Acid (**10a**). MnO_2 (34.8 g, 0.40 mol) was added with stirring to soln. of **5a** (3.48 g, 13.4 mmol) in CH_2Cl_2 (100 ml). Complete oxidation was achieved within 1 h and the MnO_2 removed by suction. Evaporation of the solvent *i.v.* afforded the crude aldehyde (80% yield). A soln. of this compound (1.1 g, 4.23 mmol) in *t*-BuOH (88 ml) and 2-methylbut-2-ene (21.0 ml) was successively treated with stirring at r.t. with a soln. of $NaClO_2$ (3.5 g, 29.2 mmol) and NaH_2PO_4 (3.5 g, 28 mmol) in H_2O (35 ml). The yellow soln. turned colorless

within 2 h. Solvents were removed *i.v.*, and the residue was taken up in H_2O (90 ml). Unpolar by-products were removed by extraction with hexane (2 × 50 ml), and the aq. layer was acidified with 2N HCl to pH 3.0. Extraction with Et_2O (3 × 50 ml), washing with H_2O, drying, and evaporation gave crude **10a**. Recrystallization from heptane at −20° afforded 0.8 g (68%) of pure **10a**. M.p. 40°. IR: 3430*m* (br.), 3090*w*, 3030*w*, 2925*s*, 2855*s*, 1695*s*, 1650*s*, 1605*w*, 1500*m*, 1470*m*, 1450*m*, 1420*m*, 1370*m*, 1340*m*, 1320*m*, 1135*w*, 1030*w*, 990*w*, 975*m*, 930*m*, 850*m*, 810*m*, 695*m*. ^{1}H-NMR: 7.21 (*m*, C_6H_5); 7.09 (*dt*, CH_2CH=CH); 5.82 (*d*, CH_2CH=C*H*); 2.60 (*t*, $C_6H_5CH_2$); 2.21 (*dt*, CH_2CH=CH); 1.61 (*quint.*, $C_6H_5CH_2CH_2$); 1.45 (*quint.*, CH_2CH_2CH=CH); 1.40–1.23 (br. *s*, 5 CH_2). MS (Me_3Si ester): 347 (5, $M^+ - CH_3$), 331 (18), 257 (15), 255 (15), 165 (3), 155 (33), 143 (13), 129 (33), 117 (100), 104 (30), 91 (53), 81 (24), 75 (18), 65 (19). Anal. calc. for $C_{18}H_{26}O_2$ (274.40): C 78.80, H 9.54; found: C 78.88, H 9.53.

(E)-12-Phenyl(2,3-$^2H_2$)dodec-2-enoic Acid (**10**). Prepared from **5** (4.23 mmol) as described for **10a**: 60%. IR: 3430*m* (br.), 3090*w*, 3070*w*, 3030*w*, 2920*s*, 2855*s*, 1690*s*, 1620*s*, 1500*m*, 1470*m*, 1455*m*, 1415*m*, 1290*s*, 1095*w*, 1030*w*, 940*m*, 850*w*, 745*w*, 730*w*, 720*w*, 700*w*. ^{1}H-NMR: 7.21 (*m*, C_6H_5); 2.60 (*t*, $C_6H_5CH_2$); 2.21 (*t*, CH_2CD=CD); 1.61 (*quint.*, $C_6H_5CH_2CH_2$); 1.45 (*quint.*, CH_2CH_2CD=CD); 1.40–1.23 (br. *s*, 5 CH_2). MS: (Me_3Si ester) 349 (17, $M^+ - CH_3$), 33 (61), 257 (27), 157 (52), 144 (40), 131 (53), 118 (72), 117 (75), 104 (39), 91 (100), 83 (18), 73 (33), 65 (33). Anal. calc. for $C_{18}H_{24}{}^2H_2O_2$ (276.39): C 78.21, H 10.11; found: C 78.50, H 9.92.

12-Phenyl(2,3-$^2H_2$)dodecanoic Acids by Microbial Reduction: General Procedure. Clostridium tyrobutyricum (DSM-No. 1460) was grown, stored, and manipulated as described in [8] [14]. For the experiment in deuterium buffer (see **10a**), wet packed cells were freeze-dried for removal of H_2O (under exclusion of O_2) and resuspended in ^2H_2O. For the preparation of (2*R*,3*R*)-**11**, a total volume of 10 ml containing 0.6 mmol of sodium salt of **10**, 1.3 g of wet packed cells, 1.0 mg of tetracycline, 1.0 mM methylviologen, and 0.1M potassium phosphate buffer at pH 7.0 was shaken at 35° under an atmosphere of 1 bar $^1H_2$ gas (vessel equipped with a mercury-filled *Warburg* manometer). After 1.5 h, the H_2 uptake ceased, and the substrate was converted. The suspension was acidified to pH 1.5 with dil. H_2SO_4 soln. and extracted with Et_2O. For the preparation of (2*S*,3*S*)-**11**, in a total volume of 14 ml 0.1M potassium phosphate ^2H_2O-buffer, p^{2}H 7.0, 1 mmol of the undeuterated sodium salt of **10a** was converted under $^1H_2$ (not $^2H_2$) in the presence of 1 mM methylviologen, 1.4 mg of tetracycline, and 550 mg of freeze-dried cells of *C. tyrobutyricum* within *ca.* 40 h as described above. After extraction, drying, and evaporation, the crude acid was purified by CC on silica gel using hexane/Et_2O 6:4. Recrystallization from heptane at −20° afforded the pure acids.

(2S,3S)-12-Phenyl(2,3-$^2H_2$)dodecanoic Acid ((2*S*,3*S*)-**11**). Prepared from **10** in H_2O buffer in 63% yield as described. M.p. 59°. IR: 3420*w* (br.), 3090*w*, 3070*w*, 3030*w*, 2920*s*, 2850*s*, 2680*w*, 2165*w*, 1700*s*, 1600*w*, 1500*w*, 1470*m*, 1465*m*, 1450*m*, 1420*m*, 1310*m*, 1290*m*, 1260*m*, 1250*m*, 1240*m*, 1030*w*, 960*m*, 935*m*, 745*s*, 700*s*. ^{1}H-NMR: 7.21 (*m*, C_6H_5); 2.61 (*t*, $C_6H_5CH_2$); 232 (*d*, C*H*DCOOH); 1.61 (br. *m*, C*H*DCHDCOOH, $C_6H_5CH_2CH_2$); 1.40–1.22 (br. *s*, 7 CH_2). MS (methyl ester): 292 (3, M^+), 260 (21), 242 (5), 169 (7), 151 (7), 144 (8), 131 (7), 117 (10), 104 (27), 92 (45), 91 (100), 75 (21), 65 (16), 55 (11), 41 (21). Anal. calc. for $C_{18}H_{26}{}^2H_2O_2$ (278.40): C 77.58, H 10.91; found: C 77.58, H 10.91.

(2S,3S)-12-Phenyl(2,3-$^2H_2$)dodecanoic Acid ((2*S*,3*S*)-**11**). Prepared from **10a** and ^2H_2O buffer in 69% yield as described. M.p. 59°. Spectroscopic data: identical with that of (2*R*,3*R*)-**11**.

rac-*12-Phenyl(2,3-$^2H_2$)dodecanoic Acid* (*rac*-**11**). A suspension of 10% Pt/C (250 mg) in THF (60 ml) containing 1.5 g (5.4 mmol) of the ($^2H_2$)acid **10** was stirred under H_2 until the uptake of H_2 ceased. Workup and recrystallization from heptane at −20° yielded 1.1 g (73%) of *rac*-**11**. Spectroscopic data: identical with that of (2*R*,3*R*)-**11**.

Mandelate Diesters: General Procedure. To a soln. of 0.36 mmol of the corresponding ω-phenyl(^{2}H)-dodecanoic acid and 4-(dimethylamino)pyridine (1 mg) CH_2Cl_2 (3 ml), methyl (+)-(*S*)-mandelate (60.0 mg, 0.36 mmol) and dicyclohexylcarbodiimide (74.6 mg, 0.36 mmol) were added with stirring at −10°. Stirring was continued for 4 h at −10°, followed by removal of solids by suction and evaporation. Addition of CH_2Cl_2 (3.0 ml) precipitated the last amounts of dicyclohexylurea, and after removal of the solids by filtration and evaporation, the mandelate diesters were purified by CC on silica gel with hexane/Et_2O 9:1 (TLC control (hexane/Et_2O 8:2)): 100 mg (64%). IR (diesters of (2*R*,3*R*)-**11** and (2*S*,3*S*)-**11**): 3090*w*, 3070*w*, 3030*w*, 3000*w*, 2930*s*, 2855*s*, 2170*w*, 1760*s*, 1745*s*, 1605*w*, 1500*m*, 1455*m*, 1435*m*, 1350*m*, 1270*m*, 1215*s*, 1170*s*, 1080*w*, 1050*m*, 1030*m*, 750*m*, 740*m*, 700*s*. IR (diesters of (2*S*)-**9**, (2*R*)-**9**, and (2*R*)-**13**): 3090*w*, 3070*w*, 3030*w*, 2930*s*, 2860*s*, 2215*w*, 1755*s*, 1730*m*, 1600*w*, 1500*m*, 1470*m*, 1450*m*, 1375*w*, 1370*w*, 1270*s*, 1240*s*, 1185*s*, 1170*s*, 1125*s*, 1080*m*, 1020*m*, 1000*m*, 765*m*, 740*m*, 720*m*, 700*m*. ^{1}H-NMR (diesters of (2*S*,3*S*)-**11** and (2*R*,3*R*)-**11**): 7.42 (*m*, $C_6H_5CHCOOMe$); 7.21 (*m*, $C_6H_5CH_2$); 5.92 (*s*, $C_6H_5CHCOOMe$); 3.72 (*s*, CH_3O); 2.60 (*t*, $C_6H_5CH_2$); 2.455 (*d*, CDHCD*H*COO, for (2*S*,3*S*)-**11**); 2.40 (*d*, CDHCD*H*COO, for (2*R*,3*R*)-**11**); 1.81–1.65 (*m*, $C_6H_5CH_2CH_2$, CD*H*CDHCOO); 1.40–1.22 (*m*, 7 CH_2). ^{1}H-

NMR (diesters of (2*S*)-**9**, (2*R*)-**9**, and (2*R*)-**13**): 7.42 (*m*, $C_6H_5CHCOOMe$); 7.21 (*m*, $C_6H_5CH_2$); 5.92 (*s*, $C_6H_5CHCOOMe$); 3.71 (*s*, CH_3O); 2.60 (*t*, $C_6H_5CH_2$); 2.41 (*t*, CDHCOO, for (2*R*)-**9** and (2*R*)-**13**); 2.465 (*t*, CDHCOO, for (2*S*)-**9**); 1.81–1.65 (*m*, $C_6H_5CH_2CH_2$, $CH_2CDHCOO$); 1.40–1.22 (*m*, 7 CH_2, 6 CH_2 for (2*R*)-**13**). MS (diesters of (2*S*,3*S*)-**11** and (2*R*,3*R*)-**11**): 427, 426 (0.03, M^+ and $M^+ + 1$), 381 (0.18), 277 (2), 259 (42), 150 (49), 131 (25), 117 (21), 105 (28), 92 (23), 91 (100), 77 (9), 65 (4), 55 (11), 41 (11). MS (diesters of (2*S*)-**9** and (2*R*)-**9**): 426, 425 (0.02, M^+ and $M^+ + 1$), 380 (0.2), 258 (43), 150 (49), 131 (21), 117 (20), 105 (25), 92 (20), 91 (100), 77 (8), 65 (5), 55 (15), 41 (14). MS (diester of (2*R*)-**13**): 352 (0.04, $M^+ - COOCH_3$), 244 (32), 150 (29), 131 (15), 117 (12), 105 (20), 92 (13), 91 (100), 77 (6), 65 (4), 55 (8), 41 (9).

1-(Trimethylsilyl)-11-phenylundec-1-yne (**14**). A soln. of bis(trimethylsilyl)acetylene (3.0 g, 18.2 mmol) in dry THF (60 ml) was gradually treated with stirring at r.t. with 13.4 ml (20.1 mmol) of a 1.5M soln. of $CH_3Li/LiBr$. After 30 min, the soln. was cooled to −78° and a soln. of **1** (4.0 g) in dry HMPA (10 ml) added. The mixture was allowed to come to r.t. and stirring continued for 60 min. The soln. was poured into 10% Na_2CO_3 soln. (30 ml) and the aq. layer extracted with Et_2O (2 × 20 ml). After washings (H_2O, brine), drying, and evaporation, the product was chromatographed with hexane on silica gel: 3.1 g (73%) of a colorless liquid. IR: 3090*w*, 3070*w*, 3030*m*, 3000*w*, 2930*s*, 2860*s*, 2190*s*, 1620*w*, 1515*m*, 1470*m*, 1465*m*, 1250*s*, 1030*m*, 840*s*, 765*s*, 730*m*, 700*s*. ^{1}H-NMR: 7.21 (*m*, C_6H_5); 2.61 (*t*, $C_6H_5CH_2$); 2.21 (*t*, $CH_2C{\equiv}C$); 1.61 (*quint.*, $C_6H_5CH_2CH_2$); 1.52 (*quint.*, $CH_2CH_2C{\equiv}C$); 1.40–1.22 (br. *s*, 5 CH_2); 0.16 (*s*, $(CH_3)_3Si$). MS: 300 (2, M^+), 285 (52), 269 (1), 226 (8), 204 (12), 183 (2), 168 (6), 155 (3), 143 (10), 135 (19), 109 (11), 91 (37), 80 (8), 73 (100), 59 (18), 39 (11). HR-MS: 300.2303 ($C_{20}H_{32}Si$, M^+, calc. 300.2274).

(E)-11-Phenyl(1-^{2}H)undec-1-ene (**16**). A soln. of **14** (0.52 g, 1.73 mmol) in dry Et_2O (10 ml) was treated with stirring at 0° with neat DIBAL-H (387 µl, 2.1 mmol). The mixture was kept at 0° for 60 min and then at r.t. for 5 h. Hydrolysis with ^2H_2O (> 99% ^2H) at 0°, extraction with Et_2O, drying, and evaporation afforded a crude (*Z*)-vinylsilane which was purified by CC on silica gel coated with $AgNO_3$ (10%) using hexane for elution: 270 mg (52%) of a colorless liquid. A soln. of this vinylsilane (199.3 mg, 0.66 mmol) and conc. HCl (100 µl) in CH_3CN (4 ml) was refluxed for 15 min. After cooling, ice/H_2O (4 ml) was added and the product extracted with pentane (2 × 15 ml). The combined org. layers were washed with H_2O (2 × 5 ml), dried, and evaporated. CC on silica gel, coated with $AgNO_3$ (10%), using pentane gave 84 mg (55%) of a colorless liquid. ^{1}H-NMR: 88% of (*E*)- and 12% of (*Z*)-isomer. IR: 3090*w*, 3070*w*, 3030*m*, 3000*w*, 2930*s*, 2860*s*, 2250*w*, 1730*w*, 1620*w*, 1600*w*, 1500*m*, 1465*m*, 1460*m*, 800*m*, 740*m*, 725*m*, 700*s*. ^{1}H-NMR: 7.21 (*m*, C_5H_5); 5.82 (*m*, $CH_2CH{=}C$); 4.99 (*d*, J = 14.8, CH=C*H*D); 2.61 (*t*, $C_6H_5CH_2$); 2.05 (*dt*, $CH_2CH{=}C$); 1.62 (*quint.*, $C_6H_5CH_2CH_2$); 1.40–1.22 (br. *s*, 6 CH_2). MS: 231 (12, M^+), 188 (0.5), 174 (0.5), 159 (0.5), 145 (1), 131 (6), 117 (14), 104 (100), 98 (1), 91 (80), 79 (2), 65 (3), 55 (11), 41 (11). HR-MS: 231.2092 ($C_{17}H_{25}{}^2H$, M^+, calc. 231.2090).

(Z)-11-Phenyl(1-^{2}H)undec-1-ene (**16a**). Prepared from **14** *via* reversal of hydrolytic steps (1. H_2O, 2. ^2HCl) in 43% overall yield. ^{1}H-NMR: 88% of (*Z*)- and 12% of (*E*)-isomer. IR: 3090*w*, 3070*w*, 3030*m*, 3000*w*, 2930*s*, 2860*s*, 2240*w*, 1620*w*, 1600*w*, 1485*m*, 1465*m*, 1460*m*, 980*m*, 920*w*, 750*m*, 740*m*, 700*s*. ^{1}H-NMR: 7.21 (*m*, C_6H_5); 5.82 (*m*, $CH_2CH{=}C$); 4.92 (*d*, J = 11.4, CH=C*H*D); 2.61 (*t*, $C_6H_5CH_2$); 2.05 (*dt*, $CH_2CH{=}C$); 1.62 (*quint.*, $C_6H_5CH_2CH_2$); 1.40–1.22 (br. *s*, 6 CH_2). MS: identical with that of **16**.

(Z)-11-Phenyl(1,2-$^2H_2$)undec-1-ene (**18**) *and (E)-11-Phenyl(1,2-$^2H_2$)undec-1-ene* (**18a**). To a soln. of **14** (1.3 g, 4.0 mmol) and quinoline (100 µl) in dry hexane (130 ml), *Lindlar*'s catalyst (*Fluka*; 300 mg) was added. After the uptake of 1 equiv. of $^2H_2$ gas, the catalyst was filtered off and the soln. extracted with 2N HCl (2 × 60 ml) and H_2O (2 × 60 ml). Evaporation of the solvent yielded a 5:1 mixture of (*Z*)- and (*E*)-vinylsilanes **17** and **17a**, resp., which was separated by MPLC on silica gel, coated with 10% $AgNO_3$, using hexane/$CHCl_3$ 9:1. The pure compounds were desilylated as described for **16**. Overall yield: 390 mg (33%) of **18** and 80 mg (8%) of **18a**, with identical spectra. IR: 3090*w*, 3070*w*, 3030*m*, 3000*w*, 2930*s*, 2860*s*, 2280*w*, 2210*w*, 1600*m*, 1495*m*, 1470*m*, 1460*m*, 1030*w*, 885*m*, 770*m*, 720*m*, 700*s*. ^{1}H-NMR: 7.21 (*m*, C_6H_5); 4.99 (*s*, CH=C*H*D); 2.61 (*t*, $C_6H_5CH_2$); 2.03 (*t*, $CH_2CD{=}C$); 1.62 (*quint.*, $C_6H_5CH_2CH_2$); 1.40–1.22 (br. *s*, 6 CH_2). MS: 232 (9, M^+), 145 (2), 131 (10), 117 (17), 104 (100), 91 (54), 85 (2), 65 (11), 57 (3). HR-MS: 232.2157 ($C_{17}H_{24}{}^2H_2$, M^+, calc. 232.2152).

(3R)-1,1,12-Triphenyl(2,3-$^2H_2$)dodec-1-ene (**12**). In the usual manner, 198 mg (0.72 mmol) of (2*R*,3*R*)-**11** were esterified with CH_2N_2. After evaporation, the ester was redissolved in dry Et_2O (3.0 ml) and PhLi (0.90 ml, 1.8 mmol; 2M in cyclohexane/Et_2O 7:3) added with stirring at 0°. Stirring was continued at 0° for 10 min and then the soln. hydrolyzed by addition of ice/H_2O (10 ml). The crude alcohol was extracted with Et_2O (2 × 10 ml) and the extract dried and evaporated. Brief treatment with 20% H_2SO_4 in AcOH at 60° for 0.5 min yielded **12** which was purified by CC on silica gel (hexane; TLC control (hexane)): 100 mg (35%). IR: 3085*m*, 3065*m*, 3030*m*, 2930*s*, 2860*s*, 1945*w*, 1600*w*, 1495*m*, 1465*m*, 1450*m*, 1440*m*, 1260*m*, 1095*m*, 1070*m*, 1030*m*, 910*m*, 720*m*, 700*s*. ^{1}H-NMR: 7.40–7.18 (br. *m*, 3 C_6H_5); 6.08 (*d*, 0.2 H, CD(*H*)=C); 2.60 (*t*, $C_6H_5CH_2$); 2.08 (*t*, 1 H; CD*H*CD=C); 1.61 (*quint.*,

$C_6H_5CH_2CH_2$); 1.42 (*quint.*, CH_2CHD); 1.36–1.18 (br. *m*, 6 CH_2). MS: 398 (12, $M^{+\cdot}$), 397 (3), 256 (2), 207 (2), 195 (65), 194 (48), 181 (55), 180 (48), 167 (30), 131 (10), 117 (45), 116 (46), 104 (9), 92 (50), 91 (100), 77 (6), 69 (2), 65 (10), 55 (9), 48 (3), 41 (20).

(2R)-11-Phenyl(2-^{2}H)undecanoic Acid ((2*R*)-**13**). Prepared from (3*R*)-**12** (90.0 mg, 0.22 mmol) as described for (2*R*)-**9**: 30.0 mg (51%). IR: identical with that of (2*R*)-**9**. ^{1}H-NMR: identical with that of (2*R*)-**9**, except: 1.40–1.25 (br. *m*, 6 CH_2). MS (methyl ester): 277 (1, $M^{+\cdot}$), 245 (22), 227 (6), 154 (8), 131 (11), 117 (9), 104 (25), 92 (38), 91 (100), 75 (17), 65 (16), 55 (13), 41 (28). Anal. calc. for $C_{17}H_{25}{}^2HO_2$ (263.39): C 77.59, H 10.32; found: C 77.47, H 10.26.

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