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Applications of remote stereocontrol using allylstannanes: an approach to the stereoselective synthesis of aliphatic polyols

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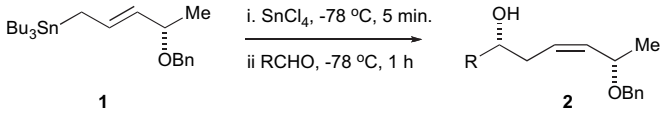
ABSTRACT

(4*R*,2*E*)-4-Benzyloxy-octa-2,7-dienyl(tributyl)stannane was transmetalated by tin(IV) chloride to generate an allyltin trichloride, which reacted with aldehydes to give (3*Z*)-1,5-*syn*-5-benzyloxynona-3,8-dien-1-ols with useful 1,5-stereocontrol. *O*-Benzylation, hydroboration and oxidation of the terminal double-bond of the product from 2-methylpropanal gave (5*R*,9*S*,6*Z*)-5,9-dibenzyloxy-10-methylundec-6-enal. Further reactions with 4-alkoxyalk-2-enylstannanes proceeded with useful 1,5-stereocontrol to give open-chain products with hydroxy or benzyloxy substituents stereoselectively disposed at remote positions along the chain.

1. Introduction

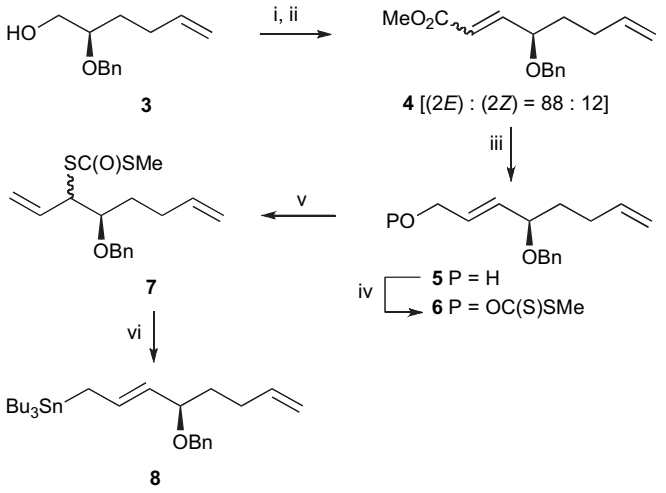
Reaction of the (4*S*)-4-benzyloxypent-2-enylstannane **1** with tin (IV) chloride generates an allyltin trichloride, which reacts with aldehydes to give (*Z*)-5-benzyloxyhex-3-en-1-ols with useful levels of stereocontrol in favour of the 1,5-*syn*-isomers **2**.[1,2] With chiral 2- and 3-alkoxyaldehydes, the 1,5-*syn*-stereoselectivity introduced by the allylstannane determines the configuration of the newly introduced hydroxyl bearing stereogenic centre, not the chirality of the aldehyde.[1,3] We here report the application of this chemistry using the (4*R*,2*E*)-4-benzyloxy-octa-2,7-dienylstannane **8** for the stereoselective synthesis of aliphatic compounds with several hydroxy and benzyloxy substituents 1,5-disposed along the open-chain.[4]



1 **2**

2. Results and discussion

The octadienylstannane **8** was prepared as outlined in Scheme 1. Swern oxidation of (*R*)-2-benzyloxyhex-5-en-1-ol (**3**) (>90% ee, Mosher's), available by reduction of the corresponding benzylidene acetal[5] using DIBAL-H, gave an aldehyde, which was condensed with methoxycarbonylmethylene(triphenyl)phosphorane to give the separable (2*E*)- and (2*Z*)-esters **4**, ratio ca. 88:12. Reduction of the (2*E*)-isomer using DIBAL-H gave the (2*E*)-alcohol **5**, which was converted into the xanthate **6**. Heating the allylic xanthate initiated a [3.3]-sigmatropic rearrangement, which gave a mixture of the diastereoisomeric dithiocarbonates **7**, ratio ca. 4:1. These were not



3 **4** [(2*E*) : (2*Z*) = 88 : 12] **7** **8**

Scheme 1. Synthesis of the octadienylstannane **8**. Reagents and conditions: (i) DMSO, $(COCl)_2$, DCM, −60 °C, 15 min, then Et_3N, −60 °C (99%); (ii) $MeO_2CCH.PPh_3$, DCM, 20 °C, 12 h (96%); (iii) DIBAL-H, −78 °C, 2 h (81%); (iv) NaH, benzene, CS_2, 20 °C, 3 h, then MeI, 20 °C, 12 h (95%); (v) toluene, heat, 20 h (98%); (vi) Bu_3SnH, AIBN, benzene, heat under reflux, 3.5 h (82%).

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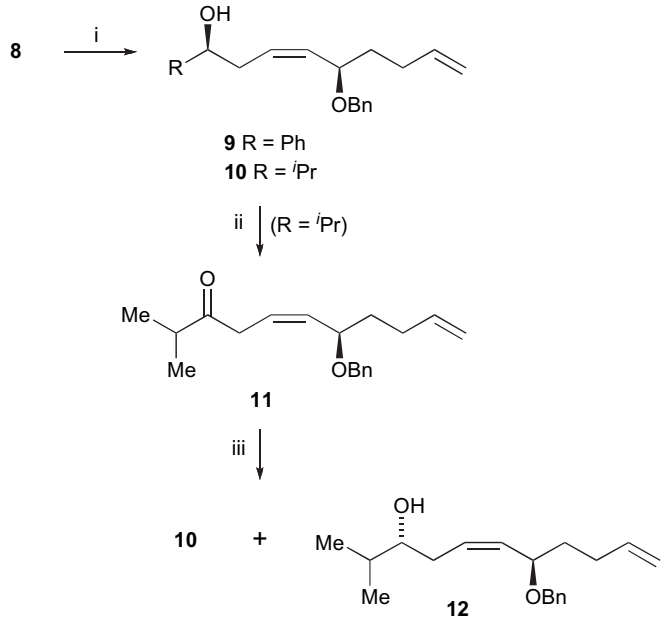
separated, instead reaction of the mixture with tributyltin hydride under free radical conditions[1] gave the allylstannane **8** predominantly as its (*E*)-isomer.

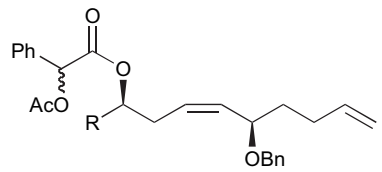
Reactions of the stannane **8** with benzaldehyde and 2-methylpropanal mediated by tin(IV) chloride were carried out at −78 °C and gave the (3*Z*)-1,5-*syn*-5-benzyloxyalk-3-enols **9** (66%) and **10** (75%) containing ca. 2% and <5% of the corresponding (3*Z*)-1,5-*anti*-epimers, respectively, see Scheme 2.



Scheme 2. Reactions of stannane **8** with simple aldehydes. Reagents and conditions: (i) **8**, $SnCl_4$, −78 °C, 5 min add aldehyde, −78 °C, 1 h (**9**, 66%, 1,5-*syn*/1,5-*anti*=98:2; **10**, 75%, 1,5-*syn*/1,5-*anti*=>95:<5); (ii), DMSO, $(COCl)_2$, −60 °C, 15 min, then $^iPr_2NEt$ (84%); (iii) $NaBH_4$, EtOH, H_2O, 20 °C, 20 h (74%; **10**/**12**=50:50).

Structures were initially assigned to the major products **9** and **10** by analogy with the corresponding reactions of stannane **1**.[1] In their ^1H NMR spectra, the vicinal vinylic coupling constants across the internal double-bonds were 11 Hz, so confirming the assigned cis-stereochemistry.

To confirm the structure of the minor (<5%) product from the reaction of stannane **8** with 2-methylpropanal, the mixture of products from this reaction was oxidised to ketone **11**. Reduction using sodium borohydride then gave a 50:50 mixture of the 1,5-*syn*- and *anti*-epimers **10** and **12**, which were separated by HPLC. These were extremely difficult to distinguish spectroscopically but one of the diastereotopic benzylic hydrogens was observed at δ 4.37 for epimer **10** and at δ 4.35 for epimer **12**. Integration of these peaks in the ^1H NMR spectrum of the product from the reaction of allystannane **8** with 2-methylpropanal, confirmed that the 1,5-*syn*/*anti*-stereoselectivity had been better than 95:5. Finally, the configurations shown for the major products **9** and **10** at their hydroxyl bearing stereogenic centres were confirmed by the relative chemical shifts of their (*R*)- and (*S*)-*O*-acetylmandelates **13**–**16**.[6,7]

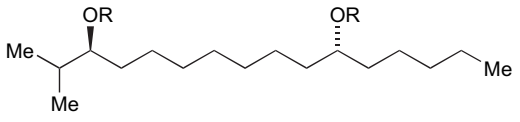


13 R = Ph, (*S*)-*O*-acetylmandelate; **14** R = Ph, (*R*)-*O*-acetylmandelate
15 R = ^{i}Pr, (*S*)-*O*-acetylmandelate; **16** R = ^{i}Pr, (*R*)-*O*-acetylmandelate

To incorporate the 1,5-*syn*-alcohol **10** into a stereoselective synthesis of an aliphatic tetrol, it was protected as its benzyl ether **17**, which was hydroborated using 9-borabicyclononane (9-BBN) to give the primary alcohol **18** after oxidation of the intermediate trialkylborane, see Scheme 3. This hydroboration was difficult to drive to completion but the use of the less hindered borane in tetrahydrofuran gave a mixture of products. Following oxidation of the alcohol, the tin(IV) chloride mediated reaction of the resulting aldehyde **19** with stannane **1** gave the 1,5-*syn*- and *anti*-products **20** and **24** in a combined yield of 76%. A sample of this mixture was oxidized to give ketone **23**, which was reduced using sodium borohydride to give a mixture of the alcohols **20** and **24** in a 1:1 ratio.

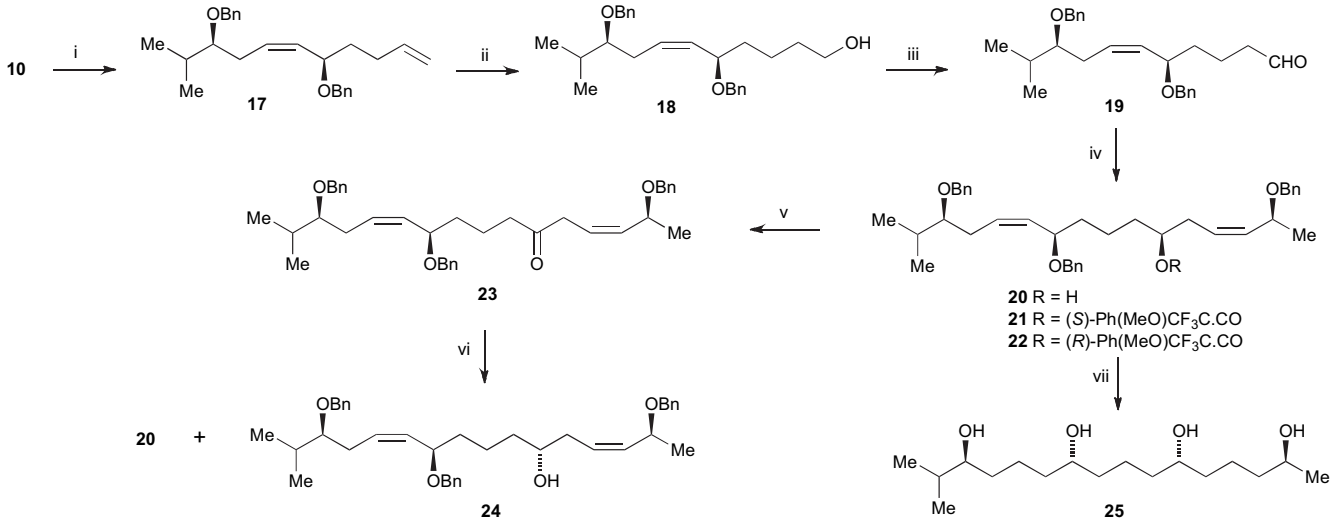
These epimers could not be separated and were again very difficult to distinguish by ^1H NMR although one of the diastereotopic benzylic hydrogens gave doublets with slightly different chemical shifts, at δ 4.35 and 4.37, for the two epimers. Integration of these peaks indicated that less than 5% of the 1,5-*anti*-alcohol **24** was present in the mixture of products from the reaction of allylstannane **1** with aldehyde **19** and so the stereoselectivity of this reaction was judged to be >95:5. Some doubling of peaks was seen in the ^{13}C NMR spectrum of the 1:1 mixture of alcohols **20** and **24**, but in the ^{13}C NMR spectrum of the product from the allylstannane reaction, only alcohol **20** could be detected with peaks due to alcohol **24**, or indeed from any other isomer, e.g., one derived from the small amount of 1,5-*anti*-product **12** carried through from the first allylstannane reaction or due to the allylstannanes being less than 100% optically pure, not being distinguished from the baseline. As a final check of stereochemical integrity, the product **20** prepared from the reaction of allylstannane **1** with aldehyde **19**, was converted into its (*R*)- and (*S*)-Mosher's derivatives **21** and **22**. For both of these, minor components accounted for less than 10% of the product mixture according to their ^{19}F NMR spectra.

Hydrogenation of the alkenyl benzyl ether **20** using 10% palladium on charcoal gave a good yield of the 2,6,10,14-*anti*,*syn*,*anti*-tetrol **25** although the use of 5% palladium on charcoal was accompanied by competing hydrogenolysis of the allylic alkoxy groups and gave diol **26**, characterised as its di-acetate **27**, as the major product.

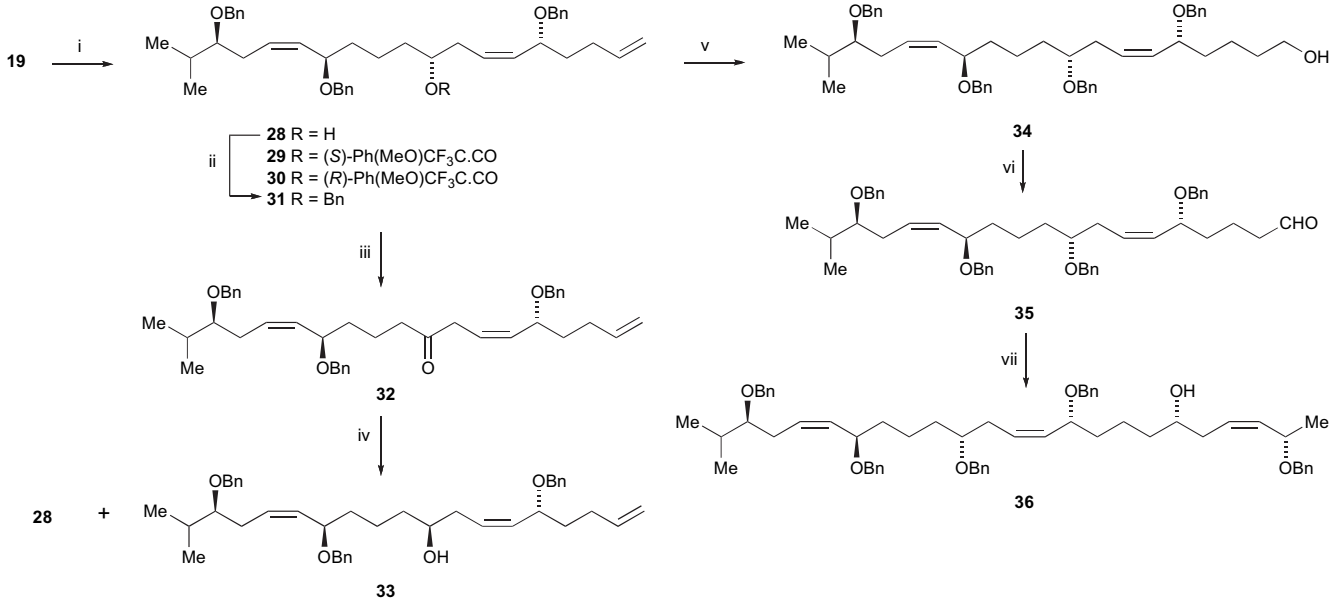


26 R = H
27 R = Ac

To take this chemistry further, the aldehyde **19** was reacted with the allyltin trichloride generated from the stannane **8** to prepare the 1,5-*syn*-alcohol **28**, see Scheme 4. The structure shown was initially assigned to the major product from this reaction by analogy with earlier work. To check the 1,5-stereoselectivity, alcohol **28** was oxidized to give ketone **32**, which was reduced using sodium borohydride to give a 1:1 mixture of epimeric alcohols **28** and **33**. These could not be separated but again were distinguished using ^1H NMR due to a difference in the chemical shift of one of the diastereotopic benzylic protons, which was observed at δ 4.54 for alcohol **28** and at δ 4.55 for its epimer **33**. Examination of the ^1H NMR spectra of the product **28** obtained from the allylstannane reaction between aldehyde **19** and stannane **8** confirned that only ca. 5% of epimer **33** was present in the product mixture. This stereoselectivity was consistent with the ^{19}F NMR spectra of the Mosher's derivatives **29** and **30**, which indicated 92:4:4 and 93:5:2 ratios of products, respectively, and with the ^{13}C NMR spectrum of the allylstannane product **28** in which minor products were not distinguished from the baseline.



Scheme 3. Synthesis of (2*S*,6*R*,10*R*,14*S*)-15-methylhexadeca-2,6,10,14-tetrol **25** Reagents and conditions: (i) NaH, DMF, 20 °C, 1 h, BnBr, $^{n}Bu_4NI$, THF, 20 °C, 12 h (86%); (ii) 9-BBN, THF, 20 °C, 2 h, then H_2O_2, NaOH, 20 °C, 12 h (64% allowing for recovered starting material); (iii) DMSO, $(COCl)_2$, −60 °C, then Et_3N (95%); (iv) **1**-$SnCl_4$, −78 °C, 1 h (76%); (v) DMSO, $(COCl)_2$, −60 °C, $^{i}Pr_2NEt$ (74%); (vi) $NaBH_4$, EtOH, H_2O, 20 °C, 3 h (95%; **20**/**22**=50:50); (vii) 10% Pd/C, MeOH, H_2, 20 °C, 3 h (88%).



Scheme 4. Further stereoselective syntheses of derivatives of aliphatic polyols Reagents and conditions: (i) **8**-$SnCl_4$, −78 °C, 1 h (72%); (ii) NaH, DMF, 0 °C, 1 h then BnBr, 20 °C, 12 h $^{n}Bu_4NI$ (68% allowing for recovered starting material); (iii) DMSO, $(COCl)_2$, −60 °C, $^{i}Pr_2NEt$ (85%); (iv) $NaBH_4$, EtOH, H_2O, 20 °C, 3 h (92%); (v) 9-BBN, THF, 20 °C, 2 h then H_2O_2, NaOH, 20 °C, 12 h (40%); (vi) DMSO, $(COCl)_2$, −60 °C then Et_3N (72%); (vii) **1**-$SnCl_4$, −78 °C, 1 h (67%).

Following protection of the alcohol **28** as its benzyl ether **31**, preliminary studies were carried out on further chain extension reactions using allylstannanes. In this work, some of the reactions, notably the hydroboration, were difficult to drive to completion perhaps because of the long aliphatic chains present in the intermediates. Nevertheless, hydroboration using 9-BBN with oxidation of the organoborane gave the alcohol **34**, which was further oxidised to give aldehyde **35**. The reaction of this aldehyde with the allyltin trichloride prepared from the stannane **1** gave a major product, which was identified as the long-chain (*Z*)-*syn*-1,5-alcohol **36** by analogy with other tin(IV) chloride mediated reactions of allylstannane **1** with aldehydes.[1] In this case, the product was not taken through to its epimeric alcohol. However, the ^{1}H and ^{13}C NMR spectra were very clean and were consistent with the allylstannane reaction having been highly stereoselective.

3. Summary and conclusions

This work shows that tin(IV) chloride mediated reactions of 4-alkoxy-substituted allylstannanes with aldehydes known to proceed with *syn*-1,5-stereoselectivity, even with chiral aldehydes, can be used to prepare open-chain compounds with several hydroxy and benzyloxy substituents at remote positions along aliphatic chains with useful levels of 1,5-stereocontrol. In the present work, the dienyl stannane **8** was useful in that hydroboration–oxidation of the terminal double bond in the products gave aldehydes which could be taken further to provide for additional stereoselective chain extension.

The examples in this paper are only illustrative; the use of enantiomeric 4-alkoxy-alk-2-enylstannanes or 4-alkoxy-alk-2,ω-dienylstannanes with different chain lengths could be used to provide access to open-chain compounds with a variety of hydroxy and alkoxy substituents at different positions along aliphatic chains.

In these studies care was taken to use allylstannanes, which were as optically pure as possible, >90% ee for both stannanes **1** and **8**. Nevertheless, minor products were expected to accumulate during the second and third iterations of reactions of the aldehydes with allylstannanes because neither the starting materials nor the allylstannanes were 100% optically pure and because minor (*Z*)-1,5-*anti*-epimers, i.e., alcohols **12** and **33**, which typically accounted for 2–5% of the product mixtures from the corresponding reactions with aldehydes, could not be separated from the major *syn*-1,5-products **10** and **28**. Indeed, the ^{19}F NMR spectra of the Mosher's derivatives **29** and **30** indicated that the major diastereoisomeric alcohol **28** accounted for 92% of the product from the reaction of allylstannane **8** with aldehyde **19** with two other products each being present at the 2–4% level. For this reason, the alcohol **36**, the product of three iterations of the allylstannane chemistry, may contain ca. 10% of accumulated minor isomers, although these were not apparent from its ^{1}H and ^{13}C NMR spectra and may have been reduced by peak shaving during chromatography.[8] Nevertheless, as the (*Z*)-1,5-*syn*/(*Z*)-1,5-*anti*-diastereoselectivity is typically 95–98:5–2, even for reactions of the 5-benzyloxyundecenal **19**, this chemistry does provide useful procedures for the stereoselective preparation of open-chain compounds with remote functionality, which would be difficult to access by other means.

More recent studies have shown that transmetalation of alkoxyalk-2-ylgermanium compounds with tin(IV) bromide, provides highly stereoselective access to allyltin tribromides giving even better overall 1,5-stereocontrol in reactions with aldehydes.[9,10] These reagents should also be useful for the preparation of compounds with functionality dispersed at remote positions along aliphatic chains as discussed here.

4. Experimental

4.1. General procedures

All non-aqueous reactions were performed under an atmosphere of argon. ^{1}H NMR spectra were recorded on Varian Unity-500 (500 MHz), Bruker AC-300 or Varian XL-300 (300 MHz) spectrometers at 300 MHz in $CDCl_3$ unless otherwise stated. ^{13}C NMR spectra were recorded on a Bruker AC-300 at 75 MHz in $CDCl_3$ and ^{19}F spectra were recorded on a Varian Unity-500 spectrometer at 470 MHz. IR spectra were recorded on a Perkin Elmer 1710FT spectrometer and mass spectra were recorded on a Kratos MS25 mass spectometer coupled to a DS55 data system. Typical isotope patterns were observed for compounds containing tin with peaks due to ^{118}Sn and ^{120}Sn reported. Melting points were determined on a Kofler Block apparatus and optical rotations were recorded on a Optical Activity AA100 polarimeter at 25 °C.

Chromatography refers to flash chromatography using either Merck silica gel 60H (40–63 m, 230–300 mesh) or May and Baker Sorbsil C60 silica gel (40–60 m) as the stationary phase.

Petroleum refers to light petroleum, bp 40–60 °C, distilled before use, and ether to diethyl ether. Solvents were dried using conventional procedures. Tin(IV) chloride and acetic anhydride were dried over and distilled from phosphorous pentoxide (P_2O_5). Brine refers to saturated aqueous sodium chloride. *n*-Butyllithium was in hexane and was titrated against 2,5-dimethoxybenzyl alcohol before use.

4.2. General procedure for tin(IV)chloride mediated reactions of aldehydes with 4-alkoxystannanes

Tin(IV) chloride (1 mol equiv) in CH_2Cl_2 cooled to −78 °C was added dropwise via a syringe to the 4-alkoxyalkenylstannane in CH_2Cl_2 at −78 °C. After 5 min, the aldehyde in CH_2Cl_2, cooled to −78 °C was added and the mixture stirred for 1 h at −78 °C before aqueous sodium hydrogen carbonate and CH_2Cl_2 were added. The mixture was allowed to warm to room temperature and the organic phase was washed with water and brine then dried ($MgSO_4$). After concentration under reduced pressure, chromatography, typically using ether/petroleum (1:3) as eluant, gave the product.

4.3. General procedure for the preparation of *O*-acetylmandelates

(*R*)- or (*S*)-*O*-Acetylmandelic acid (2 mol equiv) and DMAP (2 mg) were added to the alcohol in CH_2Cl_2 at 0 °C followed by dicyclohexylcarbodi-imide (2 mol equiv) in CH_2Cl_2. After 5 min, the cooling bath was removed and the suspension stirred for 24 h at room temperature. Following filtration, the filtercake was washed with hexane (×3) and the organic extracts were washed with aqueous hydrogen chloride (1 N), saturated sodium hydrogen carbonate, then dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography, using ether/petroleum (1:2) as eluant, gave the *O*-acetyl mandelate.

4.4. General procedure for the preparation of Mosher's esters

(*R*)- or (*S*)-2-Methoxy-2-phenyl-3,3,3-trifluoropropanoyl chloride (1.2 mol equiv) was added to the alcohol and pyridine (2 mol equiv) in carbon tetrachloride and the mixture stirred for 12 h at room temperature. 3-Dimethylaminopropylamine (1.5 mol equiv) was added and the mixture diluted with ether. The organic extracts were washed with aqueous hydrogen chloride (1 N), saturated aqueous sodium bicarbonate and brine, then dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography of the residue, using ether/petroleum (1:3) as eluant, gave the Mosher's ester.

4.5. Methyl (4*R*,2*E*)- and (4*R*,2*Z*)-4-benzyloxy-octa-2,7-dienoate 4

DMSO (5.01 g, 0.068 mol) in CH_2Cl_2 (25 ml) was added to oxalyl chloride (4.42 g, 0.034 mol) in CH_2Cl_2 (50 ml) at −60 °C. After 5 min, the alcohol **3** (6.50 g, 0.031 mol) in CH_2Cl_2 (50 ml) was added and the mixture stirred for 15 min. Triethylamine (15.96 g, 0.155 mol) was then added and the mixture was stirred for 5 min at −60 °C before being allowed to warm to room temperature. Water (60 ml) was added and the organic layer was washed with brine (60 ml), dried ($MgSO_4$) and concentrated under reduced pressure to give (*R*)-2-benzyloxyhex-5-enal (6.40 g, 99%) as a pale yellow oil. Chromatography of a small sample using EtOAc/petroleum (1:9) as eluant gave (*R*)-2-benzyloxyhex-5-enal as a colourless oil, $[\alpha]_D$ +42 (*c* 1, $CHCl_3$) (found: M^++NH_4, 222.1486. $C_{13}H_{20}NO_2$ requires *M*, 222.1494); ν_{max} (film) 2922, 1733, 1455, 1105, 914, 739 and 698 cm^{-1}; δ_H 1.79 (2H, m, 3-*H*$_2$), 2.20 (2H, m, 4-*H*$_2$), 3.80 (1H, td, *J* 6.5, 2 Hz, 2-*H*), 4.55 and 4.68 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.98–5.07 (2H, m, 6-*H*$_2$), 5.78 (1H, ddt, *J* 17, 10, 6.5 Hz, 5-*H*), 7.30 (5H, m, Ar*H*) and 9.68 (1H, d, *J* 2 Hz, 1-*H*); δ_C 29.0, 29.5, 72.8, 83.0, 116.0, 128.2, 128.3, 128.7, 137.4, 137.5 and 204.0; *m*/*z* (C.I./NH_3) 222 (M^++18, 100%) and 205 (M^++1, 2).

(*R*)-2-Benzyloxyhex-5-enal (6.40 g, 0.031 mol) in CH_2Cl_2 (50 ml) was added to methoxycarbonylmethylene(triphenyl)-phosphorane (11.0 g, 0.034 mol), in CH_2Cl_2 (60 ml) for 15 min at 20 °C. After 12 h at 20 °C, water (50 ml) was added and the organic layer dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography with preabsorbtion onto the silica, using ether/petroleum (1:9) as eluant, gave the (*Z*)-isomer of the *title compound* **4** (863 mg, 11%) as a colourless oil, $[\alpha]_D$ −6.4 (*c* 1, $CHCl_3$) (found: M^++H, 261.1497. $C_{16}H_{21}O_3$ requires *M*, 261.1491); ν_{max} (film) 2950, 1724, 1641, 1455, 1206, 1094, 1029, 914, 825, 736 and 698 cm^{-1}; δ_H 1.58–1.86 (2H, m, 5-*H*$_2$), 2.21 (2H, m, 6-*H*$_2$), 3.72 (3H, s, O*Me*), 4.43 and 4.53 (each

1H, d, *J* 12 Hz, C*H*HPh), 4.95–5.10 (3H, m, 4-*H* and 8-H_2), 5.84 (1H, ddt, *J* 17, 10, 6.5 Hz, 7-*H*), 5.92 (1H, dd, *J* 12, 1 Hz, 2-*H*), 6.21 (1H, dd, *J* 12, 9 Hz, 3-*H*) and 7.32 (5H, m, Ar*H*); δ_C 29.7, 34.3, 51.5, 71.6, 74.8, 114.9, 121.0, 127.7, 128.0, 128.5, 138.4, 138.6, 151.5 and 166.4; *m*/*z* (C.I./NH_3) 261 (M^++1, 100%); followed by the (*E*)-isomer of the *title compound* **4** (6.91 g, 85%) as a colourless oil; $[\alpha]_D$ +42 (*c* 1, $CHCl_3$) (found: M^++NH_4, 278.1752. $C_{16}H_{24}NO_3$ requires *M*, 278.1756); ν_{max} (film) 2948, 1726, 1659, 1436, 1273, 1168, 1096, 915, 736 and 698 cm^{-1}; δ_H 1.59–1.82 (2H, m, 5-H_2), 2.17 (2H, m, 6-H_2), 3.77 (3H, s, O*Me*), 3.99 (1H, m, 4-*H*), 4.38 and 4.59 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.93–5.03 (2H, m, 8-H_2), 5.78 (1H, ddt, *J* 17, 10, 6.5 Hz, 7-*H*), 6.05 (1H, dd, *J* 16, 1 Hz, 2-*H*), 6.89 (1H, dd, *J* 16, 6.5 Hz, 3-*H*) and 7.32 (5H, m, Ar*H*); δ_C 29.4, 34.2, 51.6, 71.2, 77.5, 115.3, 121.9, 127.8, 127.9, 128.6, 137.9, 138.2, 148.6 and 166.6; *m*/*z* (C.I./NH_3) 278 (M^++18, 100%).

4.6. (4*R*,2*E*)-4-Benzyloxyocta-2,7-dien-1-ol 5

DIBAL-H (1.0 M in hexane, 65.7 ml, 0.066 mol) was added for 50 min to the (2*E*)-isomer of the ester **4** (7.77 g, 0.03 mol) in CH_2Cl_2 (90 ml) at −78 °C. After 2 h at −78 °C, water (16.6 ml) was added and the mixture allowed to warm to room temperature then filtered through Celite and triturated with ether (2×30 ml). The ethereal extracts were dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography of the residue using ether/petroleum (1:1) as the eluant gave the *title compound* **5** (5.60 g, 81%) as a colourless oil, $[\alpha]_D$ +35 (*c* 1, $CHCl_3$) (found: M^++NH_4, 250.1811. $C_{15}H_{24}NO_2$ requires *M*, 250.1807); ν_{max} (film) 3377, 2862, 1641, 1455, 1089, 1071, 996, 975, 912, 736 and 698 cm^{-1}; δ_H 1.57 (1H, br s, O*H*), 1.59 and 1.77 (each 1H, m, 5-*H*), 2.14 (2H, m, 6-H_2), 3.81 (1H, q, *J* 4 Hz, 4-*H*), 4.19 (2H, dd, *J* 5, 1 Hz, 1-H_2), 4.37 and 4.58 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.91–5.04 (2H, m, 8-H_2), 5.62 (1H, dd, *J* 16, 8 Hz, 3-*H*), 5.73–5.88 (2H, m, 7-*H* and 2-*H*) and 7.32 (5H, m, Ar*H*); δ_C 29.8, 35.0, 63.1, 70.4, 79.0, 115.0, 127.6, 127.9, 128.5, 132.2, 132.3, 138.5 and 138.9; *m*/*z* (C.I./NH_3) 250 (M^++18, 100%) and 233 (M^++1, 5).

4.7. *S*-Methyl *O*-(4*R*,2*E*)-4-benzyloxyocta-2,7-dien-1-yl dithiocarbonate 6

The (2*E*)-alcohol **5** (5.60 g, 0.024 mol) in benzene (30 ml) was added for 20 min to sodium hydride (60% in mineral oil, 966 mg, 0.024 mol) in benzene (60 ml) at 0 °C. The reaction mixture was stirred for 1 h at 20 °C then cooled to 0 °C and carbon disulphide (7.34 g, 0.096 mol) was added. The resulting suspension was stirred for 3 h at 20 °C, cooled to 0 °C and methyl iodide (13.71 g, 0.096 mol) was added. The mixture was then stirred for 12 h at 20 °C, filtered through Celite and the solids triturated with CH_2Cl_2 (2×80 ml). The filtrate was washed with brine (40 ml), dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography of the residue using ether/petroleum (1:9) as eluant gave the *title compound* **6** (7.34 g, 95%) as a pale yellow oil, $[\alpha]_D$ +25.6 (*c* 1, $CHCl_3$) (found: M^++H, 323.1148. $C_{17}H_{23}O_2S_2$ requires *M*, 323.1139); ν_{max} (film) 2922, 1641, 1212, 1060, 970, 912, 736 and 698 cm^{-1}; δ_H 1.51 and 1.77 (each 1H, m, 5-*H*), 2.14 (2H, m, 6-H_2), 2.58 (3H, s, S*Me*), 3.83 (1H, q, *J* 6 Hz, 4-*H*), 4.37 and 4.58 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.93–5.04 (2H, m, 8-H_2), 5.14 (2H, d, *J* 5.5 Hz, 1-H_2), 5.80 (3H, m, 2-*H*, 3-*H*, 7-*H*) and 7.32 (5H, m, Ar*H*); δ_C 19.3, 29.7, 34.8, 70.6, 73.3, 78.6, 115.1, 125.6, 127.2, 128.0, 128.6, 136.9, 138.3, 138.7 and 215.8; *m*/*z* (C.I./NH_3) 323 (M^++1, 12%) and 91 (100).

4.8. *S*-(3*RS*,4*R*)-3-(4-Benzyloxyocta-1,7-dien-3-yl) *S*-methyl dithiocarbonate 7

The xanthate **6** (7.34 g, 0.023 mol) heated under reflux in toluene (80 ml) for 20 h. After concentration under reduced pressure, chromatography of the residue using ether/petroleum (1:9) as eluant afforded the *title compound* **7** (7.21 g, 98%) as a yellow oil, a 4:1 mixture of diastereoisomers (found: M^++H, 323.1139. $C_{17}H_{23}O_2S_2$ requires *M*, 323.1139); ν_{max} (film) 2929, 1646, 1095, 920, 867 and 697 cm^{-1}; δ_H (major diastereoisomer) 1.51–1.79 (2H, m, 5-H_2), 2.15 (2H, m, 6-H_2), 2.42 (3H, s, S*Me*), 3.65 (1H, m, 4-*H*), 4.55 (1H, d, *J* 12 Hz, C*H*HPh), 4.56 (1H, dd, *J* 12, 3.5 Hz, 3-*H*), 4.64 (1H, d, *J* 12 Hz, CH*H*Ph), 4.94–5.06 (2H, m, 8-H_2), 5.21 (1H, d, *J* 10 Hz, 1-*H*), 5.34 (1H, d, *J* 17 Hz, 1-*H*′), 5.78 (1H, ddt, *J* 17, 10, 6.5 Hz, 7-*H*), 5.91 (1H, ddd, *J* 17, 10.5, 9 Hz, 2-*H*) and 7.31 (5H, m, Ar*H*); δ_H (distinctive peaks due to the minor diastereoisomer) 2.42 (3H, s, S*Me*), 5.19 (1H, d, *J* 10 Hz, 1-*H*) and 5.32 (1H, d, *J* 17 Hz, 1-*H*′); δ_C (major diastereoisomer) 13.3, 30.0, 31.7, 52.3, 72.7, 80.6, 115.4, 119.0, 127.9, 128.0, 128.5, 133.8, 138.0, 138.3 and 189.4; δ_C (distinctive peaks due to the minor diastereoisomer) 31.0, 51.0, 72.3, 115.3, 118.3, 134.3 and 138.1; *m*/*z* (C.I./NH_3) 340 (M^++18, 16%) and 323 (M^++1, 100).

4.9. (4*R*,2*E*)-4-Benzyloxyocta-2,7-dien-1-yl(tributyl)stannane 8

Tributyltin hydride (7.82 g, 0.026 mol) and AIBN (10 mg) in benzene (15 ml) were added dropwise via a syringe to a degassed solution of the dithiocarbonate **7** (7.21 g, 0.022 mol) in benzene (75 ml). The mixture was heated under reflux for 3.5 h, allowed to cool to room temperature and concentrated under reduced pressure. Chromatography of the residue using triethylamine/ether/petroleum (1:2:97) as the eluant gave the *title compound* **8** (9.24 g, 82%) as a colourless oil, $[\alpha]_D$ +29 (*c* 1, $CHCl_3$) (found: $M^+-C_4H_9$, 449.1875. $C_{23}H_{37}O^{120}Sn$ requires *M*, 449.1866); ν_{max} (film) 2956, 2926, 1641, 1070, 1454, 1029, 963, 909, 731 and 696 cm^{-1}; δ_H 0.90 (9H, t, *J* 7 Hz, 3×CH_3), 1.25–1.60 (18H, m, 3×$CH_2CH_2CH_2$), 1.75 (2H, m, 5-H_2), 1.77 (2H, d, *J* 8.5 Hz, 1-H_2), 2.11 (2H, m, 6-H_2), 3.65 (1H, q, *J* 8 Hz, 4-*H*), 4.30 and 4.56 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.90–5.02 (2H, m, 8-H_2), 5.15 (1H, dd, *J* 15, 8.5 Hz, 3-*H*), 5.71–5.86 (2H, m, 2-*H*, 7-*H*) and 7.31 (5H, m, Ar*H*); δ_C 9.3, 13.7, 14.3, 27.4 (J_{C-Sn} 60), 29.2 (J_{C-Sn} 25), 29.9, 35.5, 69.5, 80.0, 114.4, 126.0, 127.3, 127.7, 128.3, 134.1, 138.7 and 138.2; δ_{Sn} −14.7; *m*/*z* (C.I./NH_3) 449 [M (^{120}Sn)$^+$−57, 4%], 447 [M (^{118}Sn)$^+$−57, 4], 308 (100) and 306 (90).

4.10. (1*S*,5*R*,3*Z*)-5-Benzyloxy-1-phenylnona-3,8-dien-1-ol 9

Following the general procedure, tin(IV) chloride (51 mg, 0.198 mmol) in CH_2Cl_2 (230 μl), the stannane **8** (100 mg, 0.198 mmol) in CH_2Cl_2 (3 ml) and benzaldehyde (21 mg, 0.198 mmol) in CH_2Cl_2 (50 μl), after chromatography using ether/petroleum (1:3) as eluant, gave the *title compound* **9** (42 mg, 66%) as a colourless oil, $[\alpha]_D$ −15.2 (*c* 1, $CHCl_3$) (found: M^++NH_4, 340.2283. $C_{22}H_{30}NO_2$ requires *M*, 340.2276); ν_{max} (film) 3418, 2922, 1055, 912, 736 and 699 cm^{-1}; δ_H 1.35 (1H, ddt, *J* 13, 9.5, 6 Hz, 6-*H*), 1.70 (1H, m, 6-*H*′), 2.08 (3H, m, 7-H_2 and O*H*), 2.40–2.62 (2H, m, 2-H_2), 4.09 (1H, m, 5-*H*), 4.31 and 4.51 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.72 (1H, dd, *J* 8, 6 Hz, 1-*H*), 4.91–5.01 (2H, m, 9-H_2), 5.49 (1H, dd, *J* 11, 9 Hz, 4-*H*), 5.68 (1H, dt, *J* 11, 7 Hz, 3-*H*), 5.77 (1H, ddt, *J* 17, 10, 6.5 Hz, 8-*H*) and 7.31(10H, m, Ar*H*); δ_C 29.7, 34.7, 38.0, 70.0, 73.8, 74.1, 114.8, 126.0, 127.6, 127.8, 128.0, 128.5, 128.6, 128.7, 134.0, 138.5, 139.0 and 144.1; *m*/*z* (C.I./NH_3) 340 (M^++18, 44%), 323 (M^++1, 11) and 197 (100).

4.11. (3*S*,7*R*,5*Z*)-7-Benzyloxy-2-methylundeca-5,10-dien-3-ol 10

Following the general procedure, tin(IV) chloride (1.03 g, 3.96 mmol) in CH_2Cl_2 (4.60 ml), the stannane **8** (2.0 g, 3.96 mmol) in CH_2Cl_2 (25 ml) and 2-methylpropanal (286 mg, 3.96 mmol) in CH_2Cl_2 (200 μl), after chromatography using ether/petroleum (1:3) as eluant, gave the *title compound* **10** (857 mg, 75%) as a colourless oil, $[\alpha]_D$ +14.0 (*c* 1, $CHCl_3$) (found: M^++H, 289.2179. $C_{19}H_{29}O_2$ requires *M*, 289.2167); ν_{max} (film) 3415, 2959, 1661, 1068, 912, 872,

735 and 698 cm^{-1}; δ_H 0.92 (6H, d, *J* 7 Hz, 1-H_3 and 2-*Me*), 1.48–1.88 (4H, m, 2-*H*, 8-H_2 and O*H*), 2.09–2.21 (4H, m, 4-H_2 and 9-H_2), 3.40 (1H, q, *J* 6 Hz, 3-*H*), 4.15 (1H, m, 7-*H*), 4.38 and 4.59 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.92–5.05 (2H, m, 11-H_2), 5.52 (1H, dd, *J* 11, 9 Hz, 6-*H*), 5.71 (1H, dt, *J* 11, 7 Hz, 5-*H*), 5.80 (1H, ddt, *J* 17, 10, 6.5 Hz, 10-*H*) and 7.32 (5H, m, Ar*H*); δ_C 17.5, 18.9, 29.7, 32.8, 33.5, 34.9, 70.2, 73.7, 76.5, 114.9, 127.6, 128.0, 128.5, 130.0, 133.8, 138.6 and 138.9; *m*/*z* (C.I./NH_3) 289 (M^++1, 3%) and 181 (100).

4.12. (7*R*,5*Z*)-7-Benzyloxy-2-methylundeca-5,10-dien-3-one 11

DMSO (36 mg, 0.458 mmol) in CH_2Cl_2 (500 μl) was added to oxalyl chloride (29 mg, 0.229 mol) in CH_2Cl_2 (500 μl) at −60 °C. After 5 min, the alcohol **10** (60 mg, 0.208 mmol) in CH_2Cl_2 (500 μl) was added and the mixture stirred for 15 min. *N*,*N*-Di-isopropylethylamine (134 mg, 1.04 mmol) was added and the mixture was stirred for 5 min at −60 °C then allowed to warm to room temperature. Water (800 μl) was added and the organic layer washed with brine (800 μl), dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography of the residue using ether/petroleum (1:3) as eluant, gave the *title compound* **11** (50 mg, 84%) as a pale yellow oil, $[\alpha]_D$ +25 (*c* 1, $CHCl_3$); ν_{max} (film) 2972, 1715, 1641, 1466, 1455, 1092, 1069, 913, 736 and 699 cm^{-1}; δ_H (C_6D_6) 0.9 and 0.94 (each 3H, d, *J* 7 Hz, 1-H_3 or 2-*Me*), 1.66 and 1.91 (each 1H, m, 8-*H*), 2.22 (3H, m, 2-*H* and 9-H_2), 2.92 (2H, m, 4-H_2), 4.08 (1H, m, 7-*H*), 4.37 and 4.65 (each 1H, d, *J* 12 Hz, C*H*HPh), 5.00–5.12 (2H, m, 11-H_2), 5.55 (1H, ddt, *J* 11, 9, 2 Hz, 6-*H*), 5.85 (1H, ddt, *J* 17, 10, 6.5 Hz, 10-*H*), 5.91 (1H, dt, *J* 11, 7 Hz, 5-*H*) and 7.13–7.40 (5H, m, Ar*H*); δ_C (C_6D_6) 18.2, 29.9, 35.2, 39.2, 40.6, 69.9, 73.6, 114.9, 125.5, 127.5, 127.9, 128.5, 133.7, 138.7, 139.5 and 209.5; *m*/*z* (C.I./NH_3) 304 (M^++18, 4%) and 52 (100).

4.13. (3*R*,7*R*,5*Z*)- and (3*S*,7*R*,5*Z*)-7-Benzyloxy-2-methylundeca-5,10-dien-3-ols 12 and 10

Sodium borohydride (1.8 mg, 0.045 mmol) in aqueous ethanol (1 ml) was added dropwise to the ketone **11** (27 mg, 0.09 mmol) in CH_2Cl_2 (1 ml) at 0 °C. After 20 h at 20 °C aqueous citric acid (5%, 500 μl) was added and the organic layer was separated, dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography of the residue using ether/petroleum (1:3) as eluant gave the *title compounds* **10** and **12** (20 mg, 74%) as a colourless oil, a 1:1 mixture; ν_{max} (film) 3454, 2959, 1640, 1068, 912, 735 and 698 cm^{-1}; *m*/*z* (C.I./NH_3) 306 (M^++18, 9%), 289 (M^++1, 8) and 181 (100). Following separation by HPLC, the less polar isomer was identified as the *title compound* **12**; δ_H 0.91 and 0.92 (each 3H, dd, *J* 7 Hz, 1-H_3 or 2-*Me*), 1.44 (1H, br s, O*H*), 1.57 (1H, m, 2-*H*), 1.68 and 1.80 (each 1H, m, 8-*H*), 2.09–2.29 (4H, m, 4-H_2 and 9-H_2), 3.39 (1H, m, 3-*H*), 4.15 (1H, m, 7-*H*), 4.35 and 4.58 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.92–5.06 (2H, m, 11-H_2), 5.51 (1H, dd, *J* 11, 9 Hz, 6-*H*), 5.73 (1H, dt, *J* 11, 7 Hz, 5-*H*), 5.81 (1H, ddt, *J* 17, 10, 6.5 Hz, 10-*H*) and 7.32 (5H, m, Ar*H*); δ 17.3, 18.8, 29.6, 32.7, 33.2, 34.7, 69.9, 73.5, 76.2, 114.7, 127.5, 127.8, 128.3, 129.7, 133.4, 138.4 and 138.8. The more polar compound had spectroscopic data identical to those of alcohol **10** prepared previously.

4.14. (5*R*,9*S*,6*Z*)-9-[(*S*)-2-Acetoxy-2-phenylacetoxy]-5-benzyloxy-9-phenylnona-1,6-diene 13

Following the general procedure, (*S*)-*O*-acetylmandelic acid and alcohol **9** (37 mg) gave the *title compound* **13** (40 mg, 70%) as a colourless oil (found: M^++NH_4, 516.2746. $C_{32}H_{38}NO_5$ requires *M*, 516.2750); ν_{max} (film) 1746, 1232, 1207, 915, 738 and 698 cm^{-1}; δ_H 1.29 and 1.65 (each 1H, m, 4-*H*), 2.00 (2H, m, 3-H_2), 2.19 (3H, s, *Me*CO), 2.53 and 2.69 (each 1H, m, 8-*H*), 3.98 (1 h, q, *J* 7 Hz, 5-*H*), 4.22 and 4.48 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.90–5.01 (2H, m, 1-H_2), 5.44 (1H, t, *J* 10 Hz, 6-*H*), 5.59 (1H, dt, *J* 11, 9 Hz, 7-*H*), 5.72 (1H, ddt, *J* 17, 10, 6.5 Hz, 2-*H*), 5.79 (1H, t, *J* 6.5 Hz, 9-*H*), 6.00 (1H, s, 2′-*H*) and 6.95–7.50 (15H, m, Ar*H*); *m*/*z* (C.I./NH_3) 516 (M^++18, 16%) and 197 (100).

4.15. (5*R*,9*S*,6*Z*)-9-[(*R*)-2-Acetoxy-2-phenylacetoxy]-5-benzyloxy-9-phenylnona-1,6-diene 14

Following the general procedure, (*R*)-*O*-acetylmandelic acid and alcohol **9** (26 mg) gave the *title compound* **14** (31 mg, 78%) as a colourless oil (found: M^++NH_4, 516.2748, $C_{32}H_{38}NO_5$ requires *M*, 516.2750); ν_{max} (film) 1746, 1232, 1207, 915, 738 and 698 cm^{-1}; δ_H 1.24 and 1.61 (each 1H, m, 4-*H*), 2.00 (2H, m, 3-H_2), 2.19 (3H, s, *Me*CO), 2.45 and 2.54 (each 1H, dt, *J* 15, 6 Hz, 8-*H*), 3.89 (1H, m, 5-*H*), 4.11 and 4.37 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.89–4.99 (2H, m, 1-H_2), 5.28 (2H, m, 6-*H*, 7-*H*), 5.72 (1H, ddt, *J* 17, 10, 6.5 Hz, 2-*H*), 5.79 (1H, t, *J* 6.5 Hz, 9-*H*), 6.00 (1H, s, 2′-H) and 7.20–7.55 (15H, m, Ar*H*); δ_C 20.7, 29.5, 34.5, 34.6, 69.9, 73.4, 74.5, 76.7, 114.7, 126.3, 126.8, 127.5, 127.7, 127.8, 127.9, 128.3, 128.5, 128.8, 129.3, 133.9, 135.3, 138.3, 138.7, 139.0, 168.1 and 170.2; *m*/*z* (C.I/NH_3) 516 (M^++18, 19%) and 197 (100).

4.16. (5*R*,9*S*,6*Z*)-9-[(*S*)-2-Acetoxy-2-phenylacetoxy]-5-benzyloxy-10-methylundeca-1,6-diene 15

Following the general procedure, (*S*)-*O*-acetylmandelic acid and alcohol **10** (19 mg) gave the *title compound* **15** (27 mg, 88%) as a colourless oil (found: M^++NH_4, 482.2894. $C_{29}H_{40}NO_5$ requires *M*, 482.2906); ν_{max} (film) 2966, 1746, 1372, 1233, 1210, 1179, 1059, 995, 915, 737 and 698 cm^{-1}; δ_H 0.63 and 0.65 (each 3H, d, *J* 7 Hz, 11-H_3 or 10-*Me*), 1.53 (1H, m, 10-*H*), 1.76 (2H, m, 4-H_2), 2.14 (2H, m, 3-H_2), 2.20 (3H, s, *Me*CO), 2.33 (2H, m, 8-H_2), 4.11 (1H, m, 5-*H*), 4.35 and 4.60 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.80 (1H, dt, *J* 8, 5 Hz, 9-*H*), 4.91–5.03 (2H, m, 1-H_2), 5.47 (1H, dd, *J* 11, 9 Hz, 6-*H*), 5.60 (1H, dt, *J* 11, 7 Hz, 7-*H*), 5.80 (1H, ddt, *J* 17, 10, 6.5 Hz, 2-*H*), 5.91 (1H, s, 2′-*H*) and 7.25–7.49 (10H, m, Ar*H*); δ_C 16.8, 18.4, 20.7, 29.5, 29.7, 31.0, 34.8, 70.0, 73.5, 74.7, 80.0, 114.7, 127.5, 127.7, 128.0, 128.1, 128.3, 128.7, 129.2, 133.3, 134.1, 138.4, 138.9, 168.7 and 170.2; *m*/*z* (FAB) 482 (M^++18, 0.3%), 465 (M^++1, 0.7) and 163 (100).

4.17. (5*R*,9*S*,6*Z*)-9-[(*R*)-2-Acetoxy-2-phenylacetoxy]-5-benzyloxy-10-methylundeca-1,6-diene 16

Following the general procedure, (*R*)-*O*-acetylmandelic acid and alcohol **10** (16 mg) gave the *title compound* **16** (23 mg, 89%) as a colourless oil (found: M^++NH_4, 482.2885. $C_{29}H_{40}NO_5$ requires *M*, 482.2906); ν_{max} (film) 2965, 1746, 1640, 1372, 1233, 1210, 1179, 1058, 915, 737 and 697 cm^{-1}; δ_H 0.90 (6H, d, *J* 7 Hz, 11-H_3, 10-*Me*), 1.43 (1H, m, 10-*H*), 1.70 and 1.85 (each 1H, m, 4-*H*), 2.05 (2H, m, 3-H_2), 2.13 (2H, t, *J* 6 Hz, 8-H_2), 2.20 (3H, s, *Me*CO), 3.94 (1H, q, *J* 7 Hz, 5-*H*), 4.11 and 4.40 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.79 (1H, q, *J* 6 Hz, 9-*H*), 4.90–5.00 (2H, m, 1-H_2), 5.18 (2H, m, 6-*H*, 7-*H*), 5.77 (1H, ddt, *J* 17, 10, 6.5 Hz, 2-*H*), 5.90 (1H, s, 2′-*H*) and 7.23–7.49 (10H, m, Ar*H*); δ_C 17.4, 18.5, 20.7, 29.3, 29.5, 31.3, 34.6, 69.7, 73.1, 74.8, 79.7, 114.7, 127.5, 127.7, 127.8, 127.9, 128.3, 128.8, 129.3, 133.0, 133.9, 138.3, 138.8, 168.7 and 170.3; *m*/*z* (C.I./NH_3) 482 (M^++18, 100%).

4.18. (5*R*,9*S*,6*Z*)-5,9-Dibenzyloxy-10-methylundeca-1,6-diene 17

The alcohol **10** (980 mg, 3.40 mmol) in DMF (2 ml) was added dropwise to a suspension of sodium hydride (60% in mineral oil; 163 mg, 4.08 mmol) in DMF (4 ml) at 0 °C. The mixture was stirred for 1 h at 20 °C, then cooled to 0 °C and benzyl bromide (640 mg, 374 mmol) and tetrabutylammonium iodide (10 mg,

0.027 mmol) in THF (1 ml) were added. The mixture was stirred for 12 h at 20 °C then partitioned between ether (20 ml) and water (20 ml). The ethereal layer was washed with water (15 ml), dried ($MgSO_4$), and concentrated under reduced pressure. Chromatography of the residue using ether/petroleum (1:9) as the eluant gave the *title compound* **17** (1.10 g, 86%) as a pale yellow oil, $[\alpha]_D$ +20 (*c* 1, $CHCl_3$) (found: M^++NH_4, 396.2885. $C_{26}H_{38}NO_2$ requires *M*, 396.2902); ν_{max} (film) 2960, 1641, 1454, 1093, 1070, 1029, 912, 734 and 697 cm^{-1}; δ_H 0.93 (6H, d, *J* 6.5 Hz, 11-*H*$_3$, 10-*Me*), 1.52 (1H, m, 10-*H*), 1.77 and 1.91 (each 1H, m, 4-*H*), 2.12 (1H, m, 3-*H*$_2$), 2.25 (1H, m, 8-*H*$_2$), 3.20 (1H, dt, *J* 7, 5 Hz, 9-*H*), 4.13 (1H, m, 5-*H*), 4.31, 4.52, 4.53 and 4.55 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.91–5.02 (2H, m, 1-*H*$_2$), 5.42 (1H, dd, *J* 11, 9 Hz, 6-*H*), 5.74 (1H, dt, *J* 11, 7 Hz, 7-*H*), 5.81 (1H, ddt, *J* 17, 10, 6.5 Hz, 2-*H*) and 7.31 (10H, m, Ar*H*); δ_C 18.3, 18.5, 29.3, 29.8, 31.1, 35.1, 70.1, 72.1, 73.7, 84.3, 114.8, 127.5, 127.6, 127.8, 127.9, 128.4, 128.6, 130.4, 132.4, 138.5, 138.7 and 139.1; *m*/*z* (C.I./NH_3) 396 (M^++18, 41%), 106 (99) and 32 (100).

4.19. (5*R*,9*S*,6*Z*)-5,9-Dibenzyloxy-10-methylundec-6-en-1-ol 18

9-Borabicyclononane (0.5 M in THF; 1.06 ml, 0.529 mmol) was added for 10 min to the diene **17** (200 mg, 0.529 mmol) in THF (2 ml) at 0 °C. After 2 h at 20 °C, the mixture was cooled to 0 °C and aqueous sodium hydroxide (21 mg, 0.529 mmol) and aqueous hydrogen peroxide (30%; 60 mg, 0.529 mmol) and water (1.5 ml) were added dropwise. The mixture was stirred for 12 h at 20 °C, then partitioned between ether (10 ml) and water (10 ml). The organic layer was washed with water (10 ml), dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography using ether/petroleum (1:10 to 1:1) as eluant, gave the *title compound* **18** (77 mg, 64% allowing for 86 mg recovered starting material) as a colourless oil, $[\alpha]_D$ +42.4 (*c* 1, $CHCl_3$) (found: M^++H, 397.2749. $C_{26}H_{37}O_3$ requires *M*, 397.2743); ν_{max} (film) 3409, 2933, 1454, 1068, 734 and 697 cm^{-1}; δ_H 0.94 (6H, d, *J* 7 Hz, 11-*H*$_3$, 10-*Me*), 1.35–1.72 (7H, m, 3×C*H*$_2$ and O*H*), 1.91 (1H, m, 10-*H*), 2.29 (2H, m, C*H*$_2$), 3.20 (1H, m, 9-*H*), 3.60 (2H, t, *J* 6.5 Hz, 1-*H*$_2$), 4.13 (1H, m, 5-*H*), 4.34, 4.51, 4.56 and 4.57 (each 1H, d, *J* 12 Hz, C*H*HPh), 5.44 (1H, t, *J* 10 Hz, 6-*H*), 5.75 (1H, dt, *J* 11, 7 Hz, 7-*H*) and 7.31 (10H, m, Ar*H*); δ_C 18.3, 18.4, 21.8, 29.2, 31.0, 32.8, 35.6, 62.8, 70.0, 72.1, 74.2, 84.2, 127.5, 127.6, 127.7, 128.0, 128.4, 130.3, 132.5 and 139.1; *m*/*z* (FAB) 397 (M^++1, 4%) and 91 (100).

4.20. (5*R*,9*S*,6*Z*)-5,9-Dibenzyloxy-10-methylundec-6-enal 19

DMSO (41 mg, 0.53 mmol) in CH_2Cl_2 (200 μl) was added to oxalyl chloride (38 mg, 0.26 mmol) in CH_2Cl_2 (200 μl) at −60 °C. After 5 min, alcohol **18** (95 mg, 0.24 mmol) in CH_2Cl_2 (200 μl) was added and the mixture stirred for 15 min before triethylamine (121 mg, 1.2 mmol) was added. The mixture was stirred for 5 min at −60 °C and allowed to warm to room temperature. Water (2 ml) was added and the layers separated. The organic layer was washed with brine (2 ml), dried ($MgSO_4$) and concentrated under reduced pressure to give the aldehyde **19** (85 mg, 95%) as a pale yellow oil. Chromatography of a sample using EtOAc/petroleum (1:9) as eluant gave the *title compound* **19** $[\alpha]_D$ +48 (*c* 1, $CHCl_3$); ν_{max} (film) 2958, 1724, 1454, 1069, 1028, 735 and 698 cm^{-1}; δ_H 0.92 (6H, d, *J* 6.5 Hz, 11-*H*$_3$, 10-*Me*), 1.41–1.79 (4H, m, 2×C*H*$_2$), 1.90 (1H, m, 10-*H*), 2.26 (2H, m, 8-*H*$_2$), 2.40 (2H, m, 2-*H*$_2$), 3.20 (1H, dt, *J* 7, 5 Hz, 9-*H*), 4.11 (1H, dt, *J* 9, 5.5 Hz, 5-*H*), 4.30 (1H, d, *J* 12 Hz, C*H*HPh), 4.52 (2H, s, C*H*$_2$Ph), 4.55 (1H, d, *J* 12 Hz, CH*H*Ph), 5.41(1H, dd, *J* 11, 9 Hz, 6-*H*), 5.75 (1H, dt, *J* 11, 7 Hz, 7-*H*), 7.25–7.35 (10H, m, Ar*H*) and 9.72 (1H, t, *J* 2 Hz, 1-*H*); *m*/*z* (C.I./NH_3) 412 (M^++18, 4%), 163 (95) and 91 (100).

4.21. (2*S*,6*S*,10*R*,14*S*,3*Z*,11*Z*)-15-Methyl-2,10,14-tribenzyloxy-hexadeca-3,11-dien-6-ol 20

Following the general procedure, tin(IV) chloride (48 mg, 0.183 mmol) in CH_2Cl_2 (214 μl), stannane **1** (85 mg, 0.183 mmol) in CH_2Cl_2 (2 ml) and the aldehyde **19** (72 mg, 0.183 mmol) in CH_2Cl_2 (100 μl) after chromatography using ether/petroleum (1:3) as the eluant gave the *title compound* **20** (79 mg, 76%) as a colourless oil, $[\alpha]_D$ +17 (*c* 1, $CHCl_3$) (found: M^++H, 571.3799. $C_{38}H_{51}O_4$ requires *M*, 571.3787); ν_{max} (film) 3461, 2930, 1454, 1070, 735 and 698 cm^{-1}; δ_H (500 MHz) 0.91(6H, d, *J* 6.5 Hz, 16-*H*$_3$, 15-*Me*), 1.25 (3H, d, *J* 6.5 Hz, 1-*H*$_3$), 1.31–1.68 (6H, m, 3×C*H*$_2$), 1.72 (1H, br s, O*H*), 1.90 (1H, m, 15-*H*), 2.14–2.32 (4H, m, 5-*H*$_2$, 13-*H*$_2$), 3.19 (1H, dt, *J* 7, 5 Hz, 14-*H*), 3.58 (1H, m, 6-*H*), 4.11 (1H, dt, *J* 9, 6.5 Hz, 10-*H*), 4.28 (1H, m, 2-*H*), 4.30, 4.38, 4.49, 4.52, 4.53 and 4.54 (each 1H, d, *J* 12 Hz, C*H*HPh), 5.41 (1H, dd, *J* 11, 9 Hz, 11-*H*), 5.51–5.61 (2H, m, 3-*H*, 4-*H*), 5.73 (1H, dt, *J* 11, 7 Hz, 12-*H*) and 7.22–7.34 (15H, m, Ar*H*); δ_C 18.2, 18.4, 21.3, 21.6, 29.1, 30.9, 35.7, 35.8, 37.0, 69.8, 70.0, 70.3, 71.3, 72.0, 74.0, 84.1, 127.4(2), 127.5, 127.6, 127.7, 127.8, 128.0(2), 128.3, 128.4, 130.2, 132.3, 135.1, 138.8 and 139.0; *m*/*z* (FAB) 571 (M^++1, 2%) and 91 (100).

4.22. (2*S*,6*S*,10*R*,14*S*,3*Z*,11*Z*)-6-[(*S*)-2-Methoxy-2-phenyl 3,3,3-trifluoropropanoyloxy]-15-methyl-2,10,14-tribenzyloxy-hexadeca-3,11-diene 21

Following the general procedure, the alcohol **20** (18 mg) gave the *title compound* **21** (24 mg, 96%) as a colourless oil, ν_{max} (film) 2957, 1745, 1454, 1271, 1169, 1071, 1027, 735, 717 and 698 cm^{-1}; δ_H 0.93 (6H, d, *J* 6.5 Hz, 16-*H*$_3$, 15-*Me*), 1.24 (3H, d, *J* 6.5 Hz, 1-*H*$_3$), 1.35–1.65 (6H, m, 3×C*H*$_2$), 1.90 (1H, m, 15-*H*), 2.14–2.49 (4H, m, 5-*H*$_2$, 13-*H*$_2$), 3.20 (1H, dt, *J* 7, 5 Hz, 14-*H*), 3.52 (3H, s, O*Me*), 4.06 (1H, m, 10-*H*), 4.22 (1H, m, 2-*H*), 4.28, 4.33, 4.50, 4.52, 4.53 and 4.54 (each 1H, d, *J* 12 Hz, C*H*HPh), 5.10 (1H, m, 6-*H*), 5.37 (1H, dd, *J* 11, 9 Hz, 11-*H*), 5.51 (2H, m, 3-*H*, 12-*H*), 5.71 (1H, dt, *J* 11, 7 Hz, 4-*H*) and 7.23–7.55 (20H, m, Ar*H*); δ_C 18.1, 18.3, 20.9, 21.3, 29.1, 30.9, 31.9, 33.3, 35.4, 55.4, 69.8, 69.9, 70.1, 72.0, 73.8, 76.7, 84.1, 126.2, 127.3, 127.4, 127.5, 127.6, 127.7, 128.3, 128.4, 129.6, 130.3, 132.1, 132.3, 135.4, 138.7, 138.9, 139.0 and 166.3; δ_F −72.82 and −72.84, ratio 10:1; *m*/*z* (C.I./NH_3) 805 (M^++19, 3%), 231 (40) and 108 (100).

4.23. (2*S*,6*S*,10*R*,14*S*,3*Z*,11*Z*)-6-[(*R*)-2-Methoxy-2-phenyl-3,3,3-trifluoropropanoyloxy]-15-methyl-2,1014-tribenzyloxy-hexadeca-3,11-diene 22

Following the general procedure, the *alcohol* **20** (21 mg) gave the *title compound* **22** (26 mg, 90%) as a colourless oil (found: M^+−C_7H_7O, 679.3608. $C_{41}H_{50}F_3O_5$ requires *M*, 679.3610); ν_{max} (film) 2957, 1744, 1454, 1260, 1169, 1071, 1027, 735 and 698 cm^{-1}; δ_H 0.93 (6H, d, *J* 6.5 Hz, 16-*H*$_3$, 15-*Me*), 1.21 (3H, d, *J* 6.5 Hz, 1-C*H*$_3$), 1.29–1.66 (6H, m, 3×C*H*$_2$), 1.90 (1H, m, 15-*H*), 2.15–2.40 (4H, m, 5-*H*$_2$, 13-*H*$_2$), 3.20 (1H, m, 14-*H*), 3.52 (3H, s, O*Me*), 4.09 (1H, m, 10-*H*), 4.16 (1H, m, 2-*H*), 4.23, 4.28 and 4.44 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.52 (2H, s, C*H*$_2$Ph), 4.53 (1H, d, *J* 12 Hz, C*H*HPh), 5.10 (1H, m, 6-*H*), 5.40 (3H, m, 3-*H*, 4-*H*, 11-*H*), 5.71 (1H, dt, *J* 11, 7 Hz, 12-*H*) and 7.24–7.54 (20H, m, Ar*H*); δ_C 18.1, 18.3, 21.3, 29.1, 30.9, 31.8, 33.5, 35.5, 55.5, 69.8, 70.0, 72.0, 73.8, 84.1, 126.0, 127.4, 127.6, 127.7, 127.8, 128.3, 128.4, 129.6, 130.4, 132.1, 132.3, 135.2, 138.7, 138.9, 139.0 and 166.3; δ_F −72.82 and −72.88, ratio 1:10; *m*/*z* (FAB) 679 (M^+−C_7H_7O, 3%), 189 (75) and 91 (100).

4.24. (2*S*,10*R*,14*S*,3*Z*,11*Z*)-15-Methyl-2,10,14-tribenzyloxy-hexadeca-3,11-dien-6-one 23

DMSO (18 mg, 0.22 mmol) in CH_2Cl_2 (200 μl) was added to oxalyl chloride (16 mg, 0.12 mol) in CH_2Cl_2 (200 μl) at −60 °C. After 5 min, the alcohol **20** (58 mg, 0.10 mmol) in CH_2Cl_2 (200 μl) was

added and the mixture stirred for 15 min. *N*,*N*-Di-isopropylethylamine (66 mg, 0.51 mmol) was added and the mixture stirred for 5 min at −60 °C then allowed to warm to room temperature. Water (800 μl) was added and the layers were separated. The organic layer was washed with brine (800 μl), dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography of the residue using ether/petroleum (1:3) as eluant gave the *title compound* **23** (43 mg, 74%) as a pale yellow oil, $[\alpha]_D$ +21 (*c* 1, $CHCl_3$) (found: M^++H, 569.3621. $C_{38}H_{49}O_4$ requires *M*, 569.3631); ν_{max} (film) 2960, 1718, 1454, 1070, 1024, 736 and 698 cm^{-1}; δ_H (500 MHz; C_6D_6) 1.01 (3H, d, *J* 6 Hz, 16-H_3), 1.03 (3H, d, *J* 6 Hz, 15-*Me*), 1.34 (3H, d, *J* 6 Hz, 1-H_3), 1.61 (1H, m, C*H*H), 1.76–1.86 (3H, m, CH*H*, CH_2), 1.91 (1H, m, 15-*H*), 2.08 (2H, m, 7-H_2), 2.27 and 2.41 (each 1H, m, 13-*H*), 2.80 (1H, ddd, *J* 17, 7, 2 Hz, 5-*H*), 2.84 (1H, ddd, *J* 17, 7, 1, Hz, 5-*H*′), 3.17 (1H, dt, *J* 6, 4 Hz, 14-*H*), 4.17 (1H, m, 10-*H*), 4.29 (1H, m, 2-*H*), 4.38, 4.44, 4.45, 4.51, 4.61 and 4.74 (each 1H, d, *J* 12 Hz, C*H*HPh), 5.61 and 5.81 (each 2H, m, vinylic *H*) and 7.17–7.48 (15H, m, Ar*H*); δ_C (C_6D_6) 18.1, 18.5, 20.1, 21.5, 29.5, 31.2, 35.6, 41.4, 42.2, 69.9, 70.0, 70.4, 72.1, 74.3, 84.2, 124.1, 127.5(2), 127.7(2), 127.9, 128.3, 128.4, 128.5, 130.5, 132.8, 135.3, 139.6, 139.8 and 205.8; *m*/*z* (FAB) 591 (M^++23, 0.5%), 569 (M^++1, 2), 353 (50) and 91 (100).

4.25. (2*S*,6*RS*,10*R*,14*S*,3*Z*,11*Z*)-15-Methyl-2,10,14-tribenzyloxyhexadeca-3,11-dien-6-ols 20 and 24

Sodium borohydride (3 mg, 0.07 mmol) in aqueous ethanol (1 ml) was added to the ketone **23** (40 mg, 0.07 mmol) in CH_2Cl_2 (1 ml) at 0 °C. After 3 h at 20 °C, aqueous citric acid (5%, 500 μl) was added and the organic layer was separated, dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography using ether/petroleum (1:3) as the eluant gave the *title compounds* **20** and **24** (38 mg, 95%) as a colourless oil, a 1:1 mixture of epimers; ν_{max} (film) 3452, 2928, 1454, 1070, 1028, 735 and 697 cm^{-1}; δ_H (500 MHz) 0.90 (6H, d, *J* 6.5 Hz, 16-H_3, 15-*Me*), 1.25 and 1.26 (each 1.5H, d, *J* 6.5 Hz, 1-H_3), 1.36–1.70 (7H, m, 3×CH_2 and O*H*), 1.90 (1H, m, 15-*H*), 2.15–2.32 (4H, m, 5-H_2, 13-H_2), 3.18 (1H, dt, *J* 7, 5 Hz, 14-*H*), 3.56 (1H, m, 6-*H*), 4.11 (1H, m, 10-*H*), 4.28 (1H, m, 2-*H*), 4.30 (1H, d, *J* 12 Hz, C*H*HPh), 4.35 and 4.37 (each 0.5H, d, *J* 12 Hz, C*H*HPh), 4.49 (1H, d, *J* 12 Hz, C*H*HPh), 4.51–4.56 (3H, m, 3×CH*H*Ph), 5.41 (1H, t, *J* 10 Hz, 11-*H*), 5.51–5.63 (2H, m, 3-*H*, 4-*H*), 5.73 (1H, m, 12-*H*) and 7.23–7.34 (15H, m, Ar*H*); δ_C (additional peaks assigned to epimer **24**) 21.5, 21.7, 35.9, 36.9, 69.9, 71.1, 74.1, 132.4, and 135.0; *m*/*z* (FAB) 571 (M^++1, 4%) and 91 (100).

4.26. (2*S*,6*R*,10*R*,14*S*)-15-Methylhexadeca-2,6,1014-tetrol 25

Palladium on charcoal (10%; 15 mg, 0.014 mmol Pd) was added to the alcohol **20** (15 mg, 0.026 mmol) in methanol (1 ml) and the suspension stirred vigorously for 6 h under an atmosphere of hydrogen then filtered through Celite, which was washed with CH_2Cl_2 (8 ml). The filtrate was concentrated under reduced pressure and chromatography of the residue using methanol/EtOAc (1:20) as eluant gave the *title compound* **25** (7 mg, 88%) as a white waxy solid, mp 85–87 °C, $[\alpha]_D$ −8.4 (*c* 1, $CHCl_3$) (found: M^++H, 305.2703. $C_{17}H_{37}O_4$ requires *M*, 305.2692); ν_{max} (film) 3331, 2927, 1462 and 1034 cm^{-1}; δ_H (500 MHz) 0.885 and 0.892 (each 3H, d, *J* 6.5 Hz, 16-H_3 or 15-*Me*), 1.17 (3H, d, *J* 6.5, 1-H_3), 1.36–1.52 (18H, m, 9×CH_2), 1.63 (1H, m, 15-*H*), 1.75 (4H, br s, 4×O*H*), 3.34 (1H, m, C*H*OH), 3.61 (2H, m, 2×C*H*OH) and 3.79 (1H, m, C*H*OH); δ_C 17.2, 18.8, 21.6, 21.8, 22.1, 23.6, 33.7, 33.8, 37.2, 37.3, 37.4, 39.1, 67.9, 71.6 and 77.2; *m*/*z* (FAB) 327 (M^++23, 2%) and 305 (M^++1, 100).

4.27. (3*S*,11*R*)-2-Methylhexadeca-3,11-diol 26

Palladium on charcoal (5%; 30 mg, 0.014 mmol Pd) was added to the alcohol **20** (60 mg, 0.105 mmol) in methanol (2 ml) and the suspension stirred vigorously for 6 h under an atmosphere of hydrogen then filtered through Celite and the filtercake washed with CH_2Cl_2 (10 ml). The filtrate was concentrated under reduced pressure and chromatography using ether as eluant gave the *title compound* **26** (20 mg, 70%) as a white waxy solid, mp 44 °C, $[\alpha]_D$ −6.4 (*c* 1, $CHCl_3$) (found: M^++NH_4, 290.3040. $C_{17}H_{40}NO_2$ requires *M*, 290.3059); ν_{max} (film) 3328, 2925, 1467 and 1131 cm^{-1}; δ_H 0.90 (9H, m, 1-H_3, 16-H_3, 2-*Me*), 1.25–1.49 (22H, m, 11×CH_2), 1.64 (1H, m, 2-*H*) and 3.35 and 3.58 (each 1H, m, C*H*OH); δ_C 14.0, 17.1, 18.9, 22.6, 25.3, 25.6, 26.0, 29.6, 29.7, 31.9, 33.5, 34.2, 37.5, 72.0 and 76.7; *m*/*z* (C.I./NH_3) 290 (M^++18, 20%), 273 (M^++1, 50) and 237 (100).

4.28. (3*S*,11*R*)-3,11-Diacetoxy-2-methylhexadecane 27

Acetic anhydride (11 mg, 0.10 mmol), triethylamine (26 mg, 0.26 mmol) and DMAP (3 mg, 0.025 mmol) were added to the alcohol **20** (14 mg, 0.05 mmol) in CH_2Cl_2 (400 μl) at 0 °C. The mixture was stirred for 4 h at 20 °C then poured into water (2 ml) and extracted with CH_2Cl_2 (2×4 ml). The organic extracts were washed with aqueous hydrogen chloride (1 N, 2×3 ml), water (4 ml) and brine (4 ml), then dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography of the residue using ether/petroleum (1:3) as eluant, gave the *title compound* **27** (16 mg, 87%) as a colourless oil, $[\alpha]_D$ −4 (*c* 1, $CHCl_3$) (found: M^++H, 357.3013. $C_{21}H_{41}O_4$ requires *M*, 357.3005); ν_{max} (film) 2932, 1737, 1373, 1244 and 1021 cm^{-1}; δ_H 0.92 (9H, m, 1-H_3, 16-H_3, 2-*Me*), 1.25–1.58 (22H, m, 11×CH_2), 1.84 (1H, m, 2-*H*), 2.07 and 2.09 (each 3H, s, *Me*CO), 4.76 (1H, q, *J* 6 Hz, 3-*H*) and 4.89 (1H, pent, *J* 6 Hz, 11-*H*); δ_C 14.0, 17.6, 18.6, 21.1, 21.3, 22.5, 25.0, 25.3, 25.5, 29.4, 29.5(2), 31.1, 31.4, 31.7, 34.0, 34.1, 74.4, 78.5, 170.9 and 171.0; *m*/*z* (FAB) 357 (M^++1, 17%), 237 (50) and 43 (100).

4.29. (5*R*,9*R*,13*R*,17*S*,6*Z*,14*Z*)-18-Methyl-5,13,17-tribenzyloxynonadeca-1,6,14-trien-9-ol 28

Following the general procedure, tin(IV) chloride (154 mg, 0.59 mmol) in CH_2Cl_2 (690 μl), the stannane **8** (299 mg, 0.59 mmol) in CH_2Cl_2 (8 ml) and the aldehyde **19** (253 mg, 0.59 mmol) in CH_2Cl_2 (150 μl), after chromatography using ether/petroleum (1:3) as eluant, gave the *title compound* **28** (261 mg, 72%) as a colourless oil, $[\alpha]_D$ +26 (*c* 1, $CHCl_3$) (found: M^++H, 611.4104. $C_{41}H_{55}O_4$ requires *M*, 611.4100); ν_{max} (film) 3456, 2932, 1641, 1497, 1455, 1206, 1070, 1029, 912, 736 and 698 cm^{-1}; δ_H (500 MHz) 0.91 (6H, d, *J* 7 Hz, 19-H_3, 18-*Me*), 1.36–1.80 (9H, m, 4×CH_2 and O*H*), 1.89 (1H, m, 18-*H*), 2.09–2.32 (6H, m, 3-H_2, 8-H_2, 16-H_2), 3.18 (1H, dt, *J* 7, 5 Hz, 17-*H*), 3.59 (1H, m, 9-*H*), 4.11 (2H, m, 5-*H*, 13-*H*), 4.29, 4.34, 4.49, 4.51, 4.53 and 4.54 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.91–5.00 (2H, m, 1-H_2), 5.40 and 5.49 (each 1H, dd, *J* 11, 9 Hz, 6-*H* or 14-*H*), 5.64 and 5.72 (each 1H, dt, *J* 11, 7 Hz, 7-*H* or 15-*H*), 5.78 (1H, ddt, *J* 17, 10, 6.5 Hz, 2-*H*) and 7.22–7.32 (15H, m, Ar*H*); δ_C 18.2, 18.3, 21.7, 29.1, 29.6, 30.9, 34.8, 35.7, 36.0, 37.0, 69.9, 70.1, 71.3, 72.0, 73.7, 74.1, 84.1, 114.7, 127.3, 127.4, 127.5, 127.6, 127.8, 128.2, 128.3, 129.1, 130.2, 132.4, 133.8, 138.4, 138.8, 138.9 and 139.0; *m*/*z* (FAB) 611 (M^++1, 2%) and 91 (100).

4.30. (5*R*,9*R*,13*R*,17*S*,6*Z*,14*Z*)-9-[(*S*)-2-Methoxy-2-phenyl-3,3,3-trifluoropropanoyloxy]-18-methyl-5,13,17-tribenzyloxynonadeca-1,6,14-triene 29

Following the general procedure, the alcohol **28** (16 mg) gave the *title compound* **29** (20 mg, 93%) as a colourless oil; ν_{max} (film) 2930, 1744, 1497, 1454, 1260, 1169, 1070, 995, 915, 735 and 698 cm^{-1}; δ_H (500 MHz) 0.89 and 0.90 (each 3H, d, *J* 6.5 Hz, 19-H_3 or 18-*Me*), 1.35–1.65 (7H, m, 3×CH_2, C*H*H), 1.72 (1H, m, CH*H*), 1.88 (1H, m, 18-*H*), 2.00–2.36 (6H, m, 3-H_2, 8-H_2, 16-H_2), 3.16 (1H, dt, *J* 7, 5 Hz, 17-*H*), 3.50 (3H, s, O*Me*), 3.99 and 4.05 (each 1H, m, 5-*H* or 13-*H*), 4.16, 4.27, 4.42, 4.48, 4.50 and 4.51 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.91 (1H, d, *J*

10.5 Hz, 1-*H*), 4.96 (1H, dd, *J* 17, 1.5 Hz, 1-*H*′), 5.07 (1H, m, 9-*H*), 5.37 (3H, m, vinylic *H*), 5.70 (1H, dt, *J* 11, 7 Hz, vinylic *H*), 5.75 (1H, ddt, *J* 17, 10.5, 7 Hz, 2-*H*) and 7.20–7.51 (20H, m, Ar*H*); δ_C 18.1, 18.3, 21.3, 29.1, 29.5, 29.7, 30.9, 32.0, 33.6, 34.7, 35.5, 55.5, 69.8, 69.9, 72.0, 73.4, 73.7, 73.8, 76.7, 84.0, 114.8, 127.1, 127.4, 127.5, 127.6, 127.7, 128.2, 128.3, 128.4, 129.6, 130.4, 132.1, 132.3, 133.9, 138.3, 138.7, 138.8, 138.9 and 166.3; δ_F −72.79, −72.82 and −72.84, ratio 93:5:2; *m*/*z* (FAB) 839 (M^++23, 1%) and 189 (100).

4.31. (5*R*,9*R*,13*R*,17*S*,6*Z*,14*Z*)-9-[(*R*)-2-Methoxy-2-phenyl-3,3,3-trifluoropropanoyloxy]-18-methyl-5,13,17-tribenzyloxynonadeca-1,6,14-triene 30

Following the general procedure, the alcohol **28** (16 mg) gave the *title compound* **30** (22 mg, 86%) as a colourless oil; ν_{max} (film) 2928, 1745, 1453, 1271, 1169, 1070, 1027, 916, 735 and 697 cm^{-1}; δ_H (500 MHz) 0.89 and 0.90 (each 3H, d, *J* 6.5 Hz, 19-H_3 or 18-*Me*), 1.28 (2H, m, CH_2), 1.44–1.62 (5H, m, 2×CH_2, C*H*H–), 1.74 (1H, m, CH*H*), 1.87 (1H, m, 18-*H*), 2.04–2.90 (6H, m, 3-H_2, 8-H_2, 16-H_2), 3.16 (1H, dt, *J* 7, 5 Hz, 17-*H*), 3.50 (3H, s, O*Me*), 3.99 and 4.04 (each 1H, m, 5-*H* or 13-*H*), 4.25 (2H, d, *J* 12 Hz, 2×C*H*HPh), 4.49 (4H, m, CH_2Ph and 2×CH*H*Ph), 4.91 (1H, d, *J* 10 Hz, 1-*H*), 4.96 (1H, dd, *J* 17, 1.5 Hz, 1-*H*′), 5.08 (1H, m, 9-*H*), 5.34 and 5.46 (each 1H, dd, *J* 11, 9 Hz, 6-*H* or 14-*H*), 5.52 and 5.68 (each 1H, dt, *J* 11, 7 Hz, 7-*H* or 15-*H*), 5.75 (1H, ddt, *J* 17, 10, 6.5 Hz, 2-*H*) and 7.20–7.50 (20H, m, Ar*H*); δ_C 18.1, 18.3, 21.0, 29.1, 29.5, 30.9, 32.1, 33.5, 34.7, 35.5, 55.5, 69.8, 70.0, 72.0, 73.4, 73.8, 76.7, 84.1, 114.8, 127.3, 127.4, 127.5, 127.6, 127.7, 128.3, 128.4, 129.6, 130.3, 132.1, 132.4, 138.3, 138.7, 138.9, 139.0 and 166.3; δ_F −72.81, −72.84 and −72.90, ratio 4:92:4;*m*/*z* (FAB) 839 (M^++23, 1%) and 189 (100).

4.32. (5*R*,13*R*,17*S*,6*Z*,14*Z*)-18-methyl-5,13,17-tribenzyloxynonadeca-1,6,14-trien-9-one 32

DMSO (13 mg, 0.15 mmol) in CH_2Cl_2 (200 μl) was added to oxalyl chloride (11 mg, 0.089 mmol) in CH_2Cl_2 (200 μl) at −60 °C. After 5 min, the alcohol **28** (45 mg, 0.074 mmol) in CH_2Cl_2 (200 μl) was added and the mixture was stirred for 15 min. *N*,*N*-Di-isopropylethylamine (48 mg, 0.37 mmol) was added and the mixture stirred for 5 min at −60 °C then allowed to warm to room temperature. Water (800 μl) was added and the organic layer washed with brine (800 μl), dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography of the residue using ether/petroleum (1:3) as the eluant gave the *title compound* **32** (38 mg, 85%) as a pale yellow oil, $[\alpha]_D$ +33 (*c* 1, $CHCl_3$); ν_{max} (film) 2931, 1718, 1641, 1454, 1093, 1069, 912, 736 and 698 cm^{-1}; δ_H (C_6D_6) 0.98 and 1.00 (each 3H, d, *J* 6 Hz, 19-H_3 or 18-*Me*), 1.55–1.95 (7H, m, 18-*H*, 3×CH_2), 2.05–2.45 (6H, m, 3-H_2, 10-H_2, 16-H_2), 2.86 (2H, m, 8-H_2), 3.15 (1H, dt, *J* 7, 5 Hz, 17-*H*), 4.07 (1H, m, C*H*OBn), 4.28 (1H, dt, *J* 9, 6 Hz, C*H*OBn), 4.35, 4.42, 4.43, 4.50, 4.62 and 4.71 (each 1H, d, *J* 12 Hz, C*H*HPh), 5.04 (1H, d, *J* 11 Hz, 1-*H*), 5.10 (1H, dd, *J* 17, 1.5 Hz, 1-*H*′), 5.55 (2H, m, 2×vinylic *H*), 5.82 (3H, m, 2×vinylic *H*, 2-*H*) and 7.12–7.45 (15H, m, Ar*H*); δ_C (C_6D_6) 18.1, 18.5, 20.1, 29.4, 29.9, 31.2, 35.2, 35.6, 41.6, 42.3, 69.9, 70.0, 72.1, 73.7, 74.3, 84.2, 114.9, 125.2, 127.5, 127.6, 127.9, 128.4, 130.5, 132.8, 133.9, 138.7, 139.5, 139.6, 139.7 and 205.9; *m*/*z* (FAB) 631 (M^++23, 0.5%), 287 (35) and 91 (90).

4.33. (5*R*,9*RS*,13*R*,17*S*,6*Z*,14*Z*)-18-Methyl-5,13,17-tribenzyloxynonadeca-1,6,14-trien-9-ols 28 and 33

Sodium borohydride (2 mg, 0.06 mmol) in aqueous ethanol (1 ml) was added to the ketone **32** (37 mg, 0.06 mmol) in CH_2Cl_2 (1 ml) at 0 °C. After 3 h at 20 °C, aqueous citric acid (5%, 500 μl) was added and the organic layer was separated, dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography of the residue using ether/petroleum (1:3) as eluant gave the *title compounds* **28** and **33** (34 mg, 92%) as a colourless oil, a 1:1 mixture of epimers; ν_{max} (film) 3450, 2932, 1641, 1454, 1093, 1069, 1029, 912, 735 and 698 cm^{-1}; δ_H (500 MHz) 0.91 (6H, d, *J* 7 Hz, 19-H_3, 18-*Me*), 1.36–1.80 (9H, m, 4×CH_2, O*H*), 1.89 (1H, m, 18-*H*), 2.06–2.32 (6H, m, 3-H_2, 8-H_2, 16-H_2), 3.18 (1H, dt, *J* 7, 5 Hz, 17-*H*), 3.59 (1H, m, 9-*H*), 4.11 (2H, m, 5-*H*, 13-*H*), 4.29, 4.34, 4.49, 4.51 and 4.53 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.54 and 4.55 (each 0.5H, d, *J* 12 Hz, CH*H*Ph), 4.91–5.01 (2H, m, 1-H_2), 5.40 (1H, dd, *J* 11, 9 Hz, vinylic *H*), 5.49, 5.64 and 5.72 (each 1H, m, vinylic *H*), 5.78 (1H, m, 2-*H*) and 7.22–7.32 (15H, m, Ar*H*); δ_C (additional peaks assigned to epimer **33**) 21.6, 34.9, 36.9, 69.8, 70.0, 71.2, 73.6, 74.0, 129.2, 130.3, 132.3, 133.7 and 138.5; *m*/*z* (FAB) 623 (M^++23, 2%), 611 (M^++1, 9), 395 (90), 287 (85) and 91 (100).

4.34. (5*R*,9*R*,13*R*,17*S*,6*Z*,14*Z*)-18-Methyl-5,9,13,17-tetrabenzyloxynonadeca-1,6,14-triene 31

The alcohol **28** (115 mg, 0.186 mmol) in DMF (1 ml) was added to sodium hydride (60% in mineral oil; 9 mg, 0.22 mmol), in DMF (1.5 ml) at 0 °C. The mixture was stirred for 1 h at 20 °C, cooled to 0 °C and benzyl bromide (35 mg, 0.21 mmol) and tetrabutylammonium iodide (5 mg, 0.014 mmol) in THF (400 μl) were added. The mixture was stirred for 12 h at 20 °C, then partitioned between ether (10 ml) and water (10 ml). The ethereal layer was washed with water (10 ml), dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography of the residue using ether/petroleum (1:9) as eluant gave the *title compound* **31** (56 mg, 68% allowing for 43 mg recovered starting material) as a pale yellow oil, $[\alpha]_D$ +23 (*c* 1, $CHCl_3$); ν_{max} (film) 2933, 1454, 1093, 1069, 1029, 735 and 697 cm^{-1}; δ_H (500 MHz) 0.93 (6H, d, *J* 6.5 Hz, 19-H_3, 18-*Me*), 1.41–1.58 (6H, m, 3×CH_2), 1.64–1.81 (2H, m, CH_2), 1.91 (1H, m, 18-*H*), 2.07–2.39 (6H, m, 3-H_2, 8-H_2, 16-H_2), 3.20 (1H, dt, *J* 7, 5 Hz, 17-*H*), 3.41 (1H, m, 9-*H*), 4.12 (2H, m, 5-*H*, 13-*H*), 4.31, 4.32 and 4.47 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.50–4.57 (5H, m, 5×CH*H*Ph), 4.95 (1H, dd, *J* 10, 1.5 Hz, 1-*H*), 5.00 (1H, dd, *J* 17, 1.5 Hz, 1-*H*′), 5.43 and 5.72 (each 2H, m, vinylic *H*), 5.80 (1H, ddt, *J* 17, 10, 6.5 Hz, 2-*H*) and 7.23–7.35 (20H, m, Ar*H*); δ_C 18.2, 18.4, 21.5, 29.2, 29.7, 31.0, 32.4, 34.2, 34.9, 35.9, 69.9, 70.0, 71.2, 72.0, 73.8, 74.2, 78.7, 84.1, 114.7, 127.3, 127.4, 127.5, 127.6, 127.7, 127.8, 128.3, 128.4, 129.4, 130.2, 132.4, 132.5, 132.7, 138.5, 138.6, 139.0 and 139.1; *m*/*z* (FAB) 701 (M^++1, 2.5%) and 163 (100).

4.35. (5*R*,9*R*,13*R*,17*S*,6*Z*,14*Z*)-18-Methyl-5,9,13,17-tetrabenzyloxynonadeca-6,14-dien-1-ol 34

9-Borabicyclononane (0.5 M in THF; 680 μl, 0.34 mmol) was added for 10 min to the triene **31** (237 mg, 0.34 mmol) in THF (1 ml) at 0 °C. After 2 h at 20 °C, the mixture was cooled to 0 °C and aqueous sodium hydroxide (14 mg, 0.34 mmol) and aqueous hydrogen peroxide (30%; 12 mg, 0.34 mmol) in water (800 μl) was added dropwise. The mixture was stirred for 12 h at 20 °C and partitioned between ether (10 ml) and water (10 ml). The organic layer was washed with water (10 ml), dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography of the residue using ether/petroleum (1:10 to 1:1) as eluant gave the *title compound* **34** (59 mg, 40% allowing for 91 mg recovered starting material) as a colourless oil, $[\alpha]_D$ +12 (*c* 1, $CHCl_3$) (found: M^++H, 719.4658. $C_{48}H_{63}O_5$ requires *M*, 719.4676); ν_{max} (film) 3451, 3030, 2933, 1454, 1093, 1069, 1028, 735 and 697 cm^{-1}; δ_H (500 MHz) 0.85 (6H, d, *J* 6.5 Hz, 19-H_3, 18-*Me*), 1.30–1.64 (12H, m, 6×CH_2), 1.83 (1H, m, 18-*H*), 2.10–2.30 (4H, m, 8-H_2, 16-H_2), 3.12 (1H, dt, *J* 7, 5 Hz, 17-*H*), 3.34 (1H, m, 9-*H*), 3.50 (2H, t, *J* 6.5 Hz, 1-H_2), 4.04 (2H, m, 5-*H*, 13-*H*), 4.23, 4.24 and 4.39 (each 1H, d, *J* 12 Hz, C*H*HPh), 4.42–4.49 (5H, m, 5×CH*H*Ph), 5.35 (2H, m, 6-*H*, 14-*H*), 5.62 and 5.66 (each 1H, dt, *J* 11, 7 Hz, 7-*H* or 15-*H*) and 7.16–7.27 (20H, m, Ar*H*); δ_C 18.1, 18.4, 21.5, 21.7, 29.2, 31.0, 32.4, 32.7, 34.2, 35.5, 35.9, 62.8, 69.9, 70.0, 71.2, 72.0, 74.2, 74.3, 78.8, 84.1, 127.3, 127.4, 127.5,

127.6, 127.7, 127.8, 128.2, 128.3, 129.3, 130.2, 132.4, 132.8, 138.8 and 139.0; *m*/*z* (FAB) 719 (M^++1, 3%), 503 (20) and 91 (100).

4.36. (5*R*,9*R*,13*R*,17*S*,6*Z*,14*Z*)-18-Methyl-5,9,13,17-tetrabenzyloxynonadeca-6,14-dienal 35

DMSO (15 mg, 0.19 mmol) in CH_2Cl_2 (200 μl) was added to oxalyl chloride (13 mg, 0.10 mmol) in CH_2Cl_2 (200 μl) at −60 °C. After 5 min, the alcohol **34** (61 mg, 0.085 mmol) in CH_2Cl_2 (200 μl) was added and the mixture was stirred for 15 min. Triethylamine (43 mg, 0.425 mmol) was added and the mixture was stirred for 5 min at −60 °C then allowed to warm to room temperature. Water (2 ml) was added and the layers were separated. The organic layer was washed with brine (2 ml), dried ($MgSO_4$) and concentrated under reduced pressure to give aldehyde **35** (35 mg, 72%) as a pale yellow oil. Chromatography of a sample using EtOAc/petroleum (1:9) as the eluant gave the *title compound* **35** as a colourless oil, $[a]_D$ +26 (*c* 1, $CHCl_3$) (found: M^++H, 717.4556. $C_{48}H_{61}O_5$ requires *M*, 717.4519); ν_{max} (film) 2932, 1724, 1454, 1093, 1069, 1028, 735 and 697 cm^{-1}; δ_H 1.00 and 1.02 (each 3H, d, *J* 6.5 Hz, 19-H_3 or 18-*Me*), 1.55–1.76 (10H, m, 5×CH_2), 1.92 (3H, m, 18-*H*, 2-H_2), 2.28 and 2.42 (each 2H, m, 8-H_2 or 16-H_2), 3.17 (1H, dt, *J* 7, 5 Hz, 17-*H*), 3.41 (1H, m, 9-*H*), 4.20 and 4.34 (each 1H, m, 5-*H* or 13-*H*), 4.40, 4.43, 4.47, 4.48, 4.50, 4.52, 4.71 and 4.77 (each 1H, d, *J* 12 Hz, C*H*HPh), 5.55 and 5.64 (each 1H, dd, *J* 11, 9 Hz, 6-*H* or 14-*H*), 5.76 and 5.81 (each 1H, dt, *J* 11, 7 Hz, 7-*H* or 15-*H*), 7.16–7.50 (20H, m, Ar*H*) and 9.38 (1H, t, *J* 1 Hz, 1-*H*); *m*/*z* (FAB) 717 (M^++1, 2%), 181 (65) and 91 (100).

4.37. (2*S*,6*S*,10*R*,14*R*,18*R*,22*S*,3*Z*,11*Z*,19*Z*)-23-Methyl-2,10,14,18,22-pentabenzyloxytetracosa-3,11,19-trien-6-ol 36

Following the general procedure, tin(IV) chloride (11 mg, 0.042 mmol) in CH_2Cl_2 (490 μl), the stannane **1** (20 mg, 0.042 mmol) in CH_2Cl_2 (2 ml) and the aldehyde **35** (30 mg, 0.042 mmol) in CH_2Cl_2 (40 μl), after chromatography using ether/petroleum (1:3) as eluant, gave the *title compound* **36** (25 mg, 67%) as a colourless oil, $[\alpha]_D$ +22 (*c* 1, $CHCl_3$) (found: M^+, 892.5693. $C_{60}H_{76}O_6$, requires *M*, 892.5720); ν_{max} (film) 3464, 2931, 1454, 1093, 1070, 1028, 735 and 697 cm^{-1}; δ_H (500 MHz) 0.89 (6H, d, *J* 7 Hz, 24-H_3, 23-*Me*), 1.24 (3H, d, *J* 6.5 Hz, 1-H_3), 1.32–1.70 (13H, m, 6×CH_2, O*H*), 1.87 (1H, m, 23-*H*), 2.13 (2H, m, CH_2), 2.14–2.35 (4H, m, 2×CH_2), 3.17 (1H, dt, *J* 7, 5 Hz, 22-*H*), 3.39 (1H, m, 6-*H*), 3.55 (1H, m, 14-*H*), 4.09 (2H, m, 2×C*H*OBn), 4.26 (1H, m, C*H*OBn), 4.28, 4.29, 4.36, 4.44, 4.47, 4.49, 4.50, 4.51, 4.52 and 4.53 (each 1H, d, *J* 12 Hz, C*H*HPh), 5.40 (2H, m, vinylic *H*), 5.53 (2H, m, vinylic *H*), 5.66 and 5.70 (each 1H, dt, *J* 11, 7 Hz, vinylic *H*) and 7.20–7.32 (25H, m, Ar*H*); δ_C 18.1, 18.4, 21.3, 21.5, 21.6, 29.2, 31.0, 32.4, 34.2, 35.6, 35.8, 35.9, 37.0, 69.9, 70.3, 71.2, 72.0, 74.2, 78.7, 84.1, 127.4, 127.6, 127.7, 127.8, 128.1, 128.2, 128.3, 129.3, 130.2, 132.4, 132.8, 135.1, 138.8 and 139.0; *m*/*z* (FAB) 893 (M^++1, 0.2%) and 91 (100).

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