Novel Regio- and Stereoselective Cascade 6-*endo*-trig Cyclisations from Polyene Acyl Radical Intermediates Leading to Steroid-Like Pentacycles and Heptacycles

by **Sandeep Handa**, **Prathap S. Nair** and **Gerald Pattenden***

School of Chemistry, The University of Nottingham, University Park, Nottingham NG7 2RD, UK

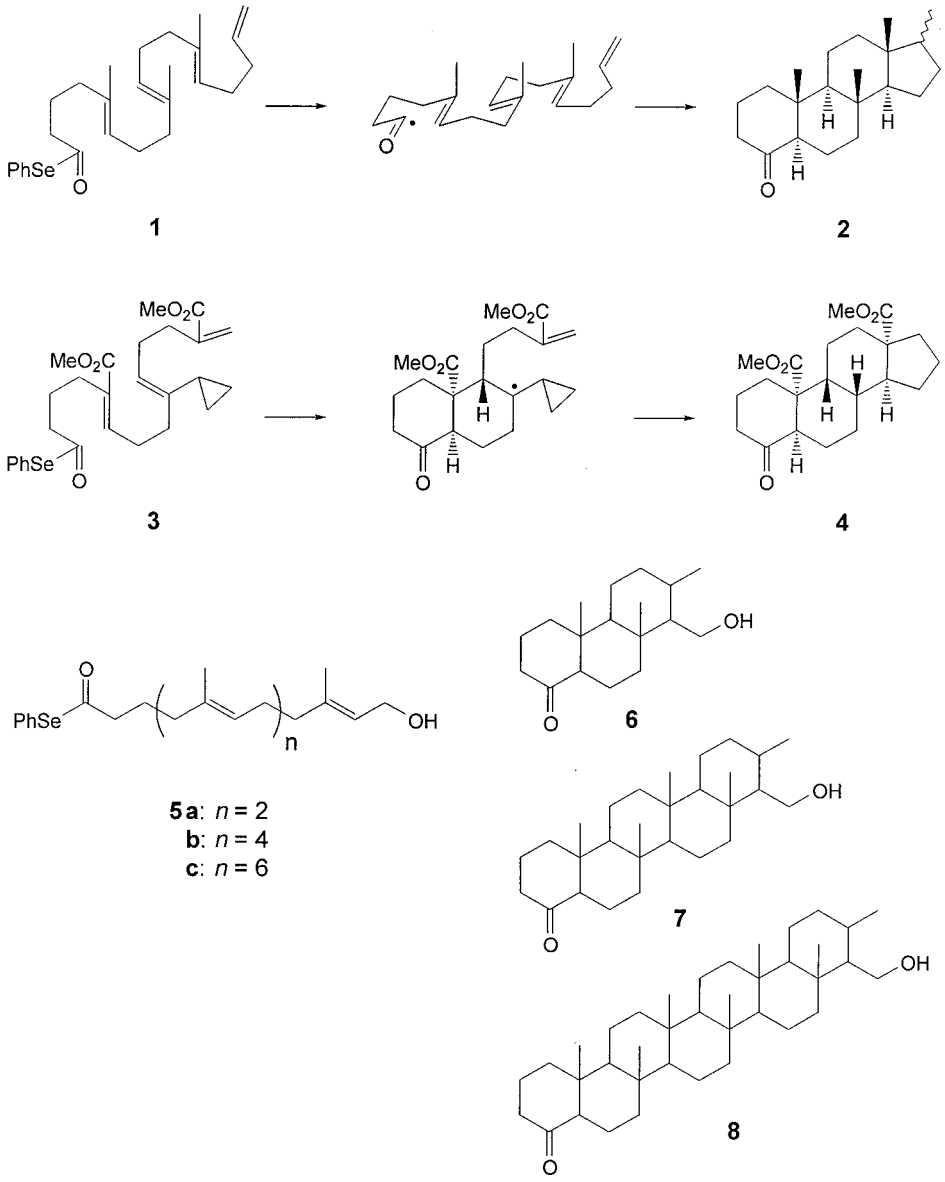
Dedicated to Professor *Albert Eschenmoser* on the occasion of his 75th birthday

In a quite remarkable regio- and stereoselective manner, each of the (all-*E*)-polyene selenoates **5a**–**c** is shown to undergo cascade radical-mediated polycyclisations *via* consecutive 6-*endo*-trig reactions, leading to the corresponding all-*trans*, *anti*, tri-, penta- and heptacycles, *i.e.*, **20**, **23**, and **25**, in good yields. The configurations of these 'steroid-like' polycycles followed from detailed examination and correlation of chemical shift data in their ^{13}C-NMR spectra.

1. Introduction. – Much of our present knowledge of the stereoelectronic factors governing consecutive *electrophilic* cyclisations of polyenes to polycyclic compounds, including steroids, stems from speculations following the so-called *Stork-Eschenmoser* hypothesis of 1955 [1], and the extensive biomimetic studies of *Johnson*'s and many other research groups that ensued [2]. Indeed, the delicate 'tuning' of the reactivity of the double bonds, in combination with careful choice of functionality for both the initiation and the termination of cyclisations, has now made electrophilic polyene cyclisations a concise synthetic route to all types of linear, angular, and other ring-fused polycycle constructions.

In more recent years, complementary 'cascade' *radical-mediated* cyclisations of polyene precursors have also become a powerful synthetic tool for the elaboration of steroid and polycyclic terpene ring systems [3]. Thus, among other cascade processes [4], our own laboratory has described serial 6-*endo*-trig cyclisations [5], together with 6-*endo*-trig cyclisations, followed by a macrocyclisation sequence [6], from the polyene acyl radical precursors **1** and **3** leading to steroid ring constructions, *i.e.*, **2** and **4**, respectively. The stereochemical outcomes of these cascade radical processes, similar to the aforementioned electrophilic polyene cyclisations, show an interesting dependence on the nature of the substituents on the alkene bonds participating in the polycyclisations, *e.g.*, the (all-*E*)-polyene **1** gives the all-*trans-anti* polycycle **2** on treatment with Bu_3SnH/AIBN, whereas bis(methoxycarbonyl)-substituted triene-selenoate **3** instead leads to the *cis-anti-cis-anti-cis* tetracycle **4** under similar reaction conditions (*Scheme 1*). Alongside other studies, we have attributed these outcomes to a degree of pre-organisation in the polyene compounds, and in the reaction intermediates, favouring the different pathways followed in the cascade radical reactions. To determine the limitations of radical-mediated processes based on cascade 6-*endo*-trig cyclisations leading to polycycle constructs containing more than four rings, we have

Scheme 1



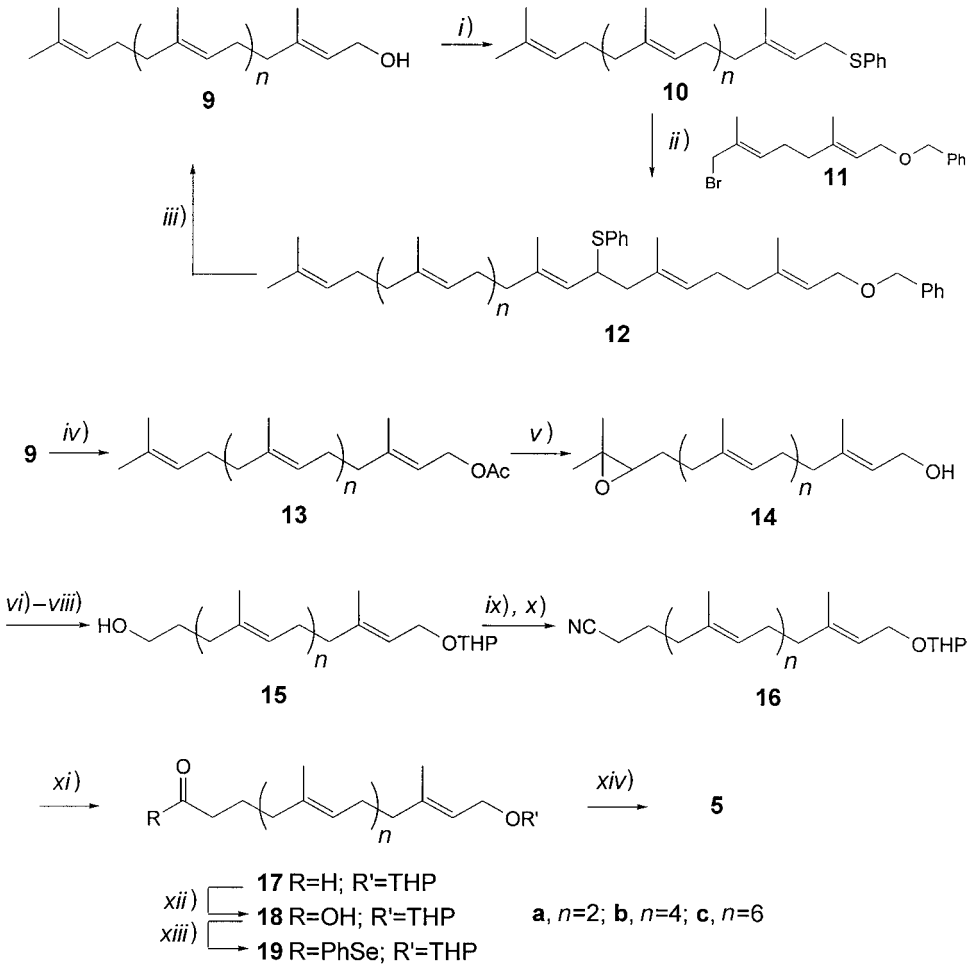
now examined the syntheses of the polyene selenoates **5a**–**c** with a view to the syntheses of the steroid-like tri-, penta- and heptacycles **6**, **7**, and **8**, respectively[1]).

2. Results and Discussion. – 2.1 *Synthesis of Precursors.* The phenyl polyeneselenoate-cyclisation precursors **5a**–**c** were all prepared by a similar strategy starting

[1]) Partially published in a preliminary communication [7].

from (all-*E*)-geranylgeraniol **9a** [8], as outlined in *Scheme 2*. Thus, phenylthioetherification of geranylgeraniol, followed by alkylation of the resulting sulfide **10a** with the known allyl bromide **11** [9], first gave the C_{30}-compound **12a**. Subsequent reduction of **12a** with Li in $EtNH_2$ at $-78°$ next led to the corresponding hexaenyl alcohol **9b**. Repetition of this sequence, *i.e.*, thioetherification, alkylation and reduction, then converted **9b** into the known octaprenyl alcohol **9c** [10][2]). Appreciable amounts (*ca.*

Scheme 2. *Synthesis of the Cyclisation Precursors* **5a–c**



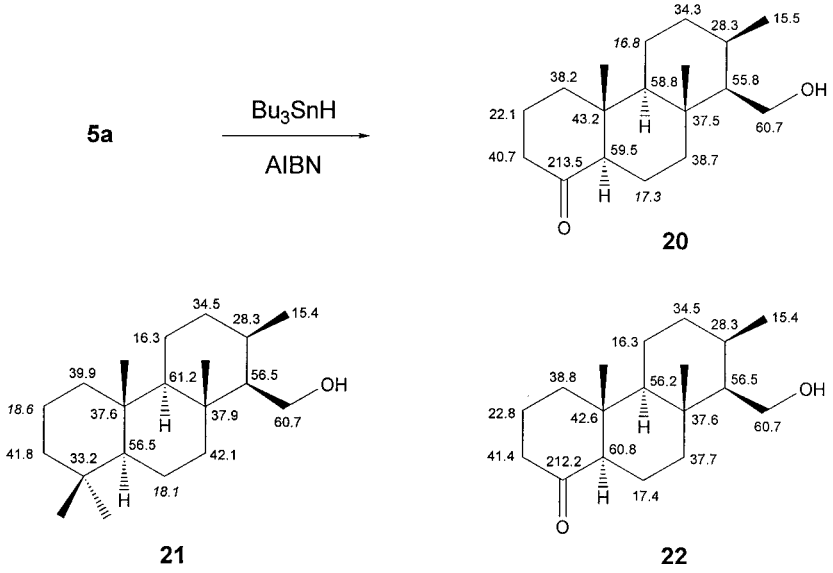
i) BuLi, THF/DMPU, $-78°$; TsCl, $0°$; LiSPh (89–93%). *ii*) BuLi, THF, $-78°$; **11**, $-78°$ (78–86%). *iii*) Li, $EtNH_2$, THF, $-78°$ (86–94%). *iv*) Ac_2O, Et_3N, DMAP, CH_2Cl_2 (95–99%). *v*) NBS, THF, H_2O; K_2CO_3, MeOH (48–63%). *vi*) HIO_4, THF, H_2O. *vii*) DHP, PPTS, CH_2Cl_2. *viii*) $NaBH_4$, Et_2O, MeOH (56–67% over 3 steps). *ix*) MsCl, Et_3N, CH_2Cl, $0°$. *x*) NaCN, DMSO, $70°$ (83–89% over 2 steps). *xi*) DIBAL-H, PhMe, $-78°$ (81–89%). *xii*) KH_2PO_4, *t*-BuOH, H_2O, $NaClO_2$, 2-methylbut-2-ene (95–99%). *xiii*) *N*-(phenylseleno)phthalimide, Bu_3P, $-30°$ (55–71%). *xiv*) $TsOH \cdot H_2O$, MeOH (83–94%).

[2]) For a similar synthetic strategy, see [9a].

5–10%) of alkene-transposition products were observed in the reductions of **12a** and **12b**, and hence the alcohols **9b** and **9c** were secured as single isomers in the (all-*E*)-configuration, following purification of the corresponding acetates **13b** and **13c** by chromatography on silica gel impregnated with silver nitrate. The acetates **13a–c** were then transformed into the cyclisation precursors **5a–c** *via* an identical synthetic route. Thus, selective epoxidation of the terminal C=C bonds in **13a–c** with *N*-bromosuccinimide (NBS) in THF/H_2O, followed by saponification [11], first produced the (all-*E*)-epoxy alcohols **14a–c**. Treatment of **14a–c** with aqueous HIO_4 resulted in hydrolysis, and simultaneous 1,2-diol cleavage [12] to produce the corresponding aldehydes, which were then converted to the primary alcohols **15a–c** in two steps. Mesylations of **15a–c**, followed by displacement reactions with NaCN next led to the nitriles **16a–c**, which were converted into the corresponding carboxylic acids **18a–c** *via* a reduction/oxidation sequence. Finally, treatment of the acids **18a–c** with *N*-(phenylseleno)-phthalimide and Bu_3P [13], followed by deprotection of the resulting selenoate **19a–c**, gave the (all-*E*)-polyene-selenoates **5a–c** in readiness for their attempted cascade radical cyclisations to the polycycles **6**, **7** and **8**, respectively.

2.2. *Cyclisation Studies.* When the phenyl triene-selenoate **5a** was subjected to our standard radical cyclisation conditions, *i.e.*, 3 mM solution of **5a** in refluxing benzene, syringe pump addition of Bu_3SnH and 2,2′-azobis(2-methylpropanenitrile) (AIBN) over 8 h, a single identifiable product was isolated in good yield (52%) by chromatography. Analysis of the spectroscopic data for this product indicated that the acyl radical intermediate had successfully undergone three sequential 6-*endo*-trig cyclisations, leading to the anticipated tricyclic ketone **6**. We were able to assign the all-*trans*,*anti*-configuration to **6**, *i.e.*, **20**, by a detailed analysis of the chemical shifts of the signals in its ^{13}C-NMR spectrum (*Scheme 3*). Thus, for the C-ring in **20**, the ^{13}C

Scheme 3. *^{13}C-NMR Analysis of the Tricyclic Ketone* **20** (assignments for those signals in *italics* may be reversed)



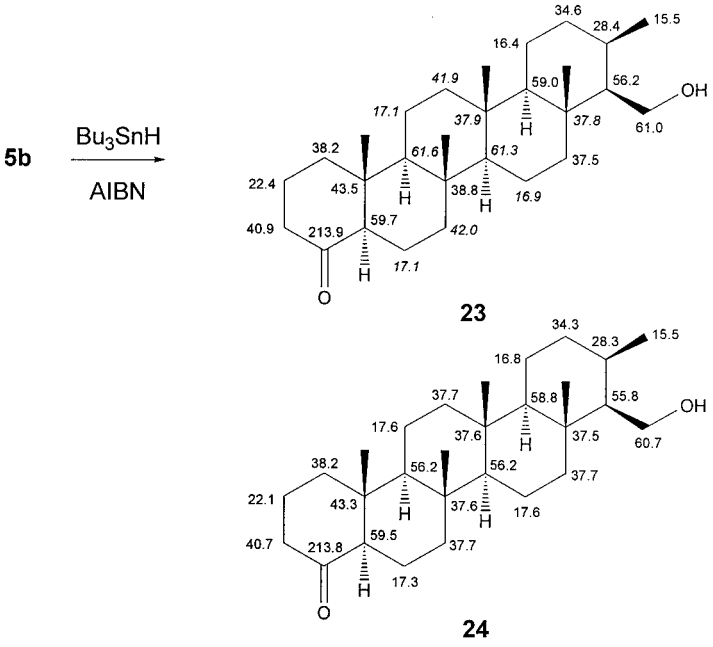
chemical shifts were compared directly with those observed for the known alcohol **21** [14]. For the A and B rings in the tricycle, we used the model proposed by *Beierbeck et al.* [15] taking into account the differing substitution at the C(4) (C-atom numbering for steroids). The results of this semi-empirical approach are shown on the formulae **22** (predicted ^{13}C chemical shifts) and **20** (observed ^{13}C chemical shifts for synthetic **6**).

The excellent correlation between the 'predicted' and observed ^{13}C chemical shifts between **20**, **21** and **22** can be taken as firm evidence for the tricylic ketone produced from the polyene **5a** having the all-*trans*,*anti*-configuration shown in formula **20**.

We next turned to the radical cyclisation of the pentaene **5b** in anticipation of synthesising the pentacyclic ketone **7**. We were pleased to find that reaction of the selenoate **5b**, under our standard radical cyclisation conditions, also led to the isolation of a single identifiable product in good yield (51%). Again, analysis of spectroscopic data indicated that this product had been generated from the acyl radical intermediate *via* a cascade of five 6-*endo*-trig cyclisations, producing the pentacylic ketone **7**. By direct comparison of the ^{13}C-NMR chemical shifts of this pentacycle with those of **20** (for rings A, B and E) and using the *Beierbeck* model to predict the ^{13}C chemical shifts for those additional structural features particular to **7**, *i.e.*, rings C and D (*Scheme 4*; **23** (observed ^{13}C chemical shifts), **24** (predicted ^{13}C chemical shifts)), we were again able to establish that the pentacyclic ketone **7** produced from the (all-*E*)-polyene-selenoate **5b** had the all-*trans*,*anti*-configuration *viz*. **23**.

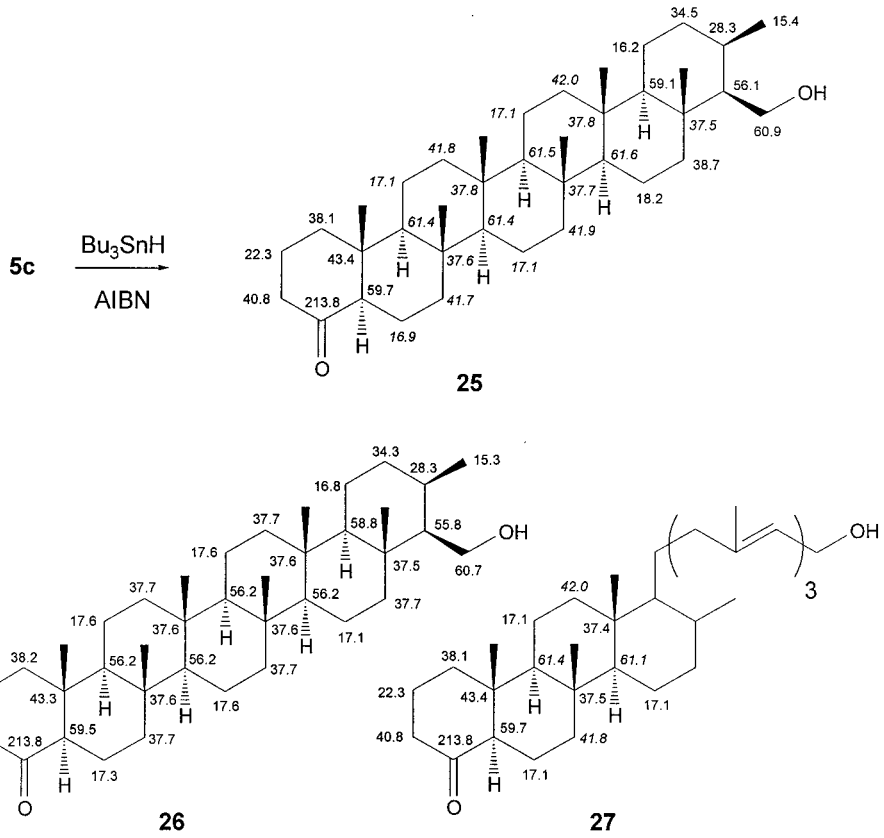
In our last cyclisation study with systems of the type **5**, treatment of the heptaene selenoate **5c** with Bu_3SnH and AIBN under our standard conditions, followed by

Scheme 4. *^{13}C-NMR Analysis of the Pentacyclic Ketone* **23** (assignments for those signals in *italics* may be reversed)



chromatography, resulted in the isolation of two products (*ca.* 45% overall yield). Detailed analysis of the spectroscopic data for the more polar of these two products (17% yield) indicated that we had indeed been successful in generating a heptacyclic ketone **8** from the acyl radical intermediate *via* a series of seven sequential 6-*endo*-trig cyclisations. Again we were able to establish that the ketone **8** had been produced from **5c** with complete all-*trans,anti*-configuration (*i.e.*, **25**) by predicting the ^{13}C-NMR chemical shifts (*i.e.*, **26**) anticipated for this heptacycle based on those of the tricycle **20** and pentacycle **24** (*Scheme 5*).

Scheme 5. *^{13}C-NMR Analysis of the Heptacyclic Ketone* **25** *and Tetracycle* **27** (assignments for those signals in *italics* may be reversed)



In addition to the heptacyclic ketone **25**, a further component (28%) was also isolated from the reaction of **5c** with Bu_3SnH and AIBN. This molecule was assigned the tetracyclic structure **27** on the basis of analysis of its ^{1}H- and ^{13}C-NMR spectroscopic data (*Scheme 5*). Furthermore, the significant correlation between the ^{13}C-NMR chemical shifts for the tetracyclic core of **27** and those of **20**, **24** and **25** establishes the all-*trans,anti*-configuration assigned to **27**.

3. Conclusion. – The regio- and stereoselective manner with which the polyene selenoates **1** and **5a**–**c** undergo radical-mediated cyclisations to the polycycles **2**, **20**, **23** and **25**, respectively, is quite remarkable, and offers a powerful synthetic method for the preparation of fused six-membered rings, akin to steroids. The *Stork-Eschenmoser* hypothesis [1] has been a useful guiding principle in synthetic planning involving *electrophilic* polyene cyclisations, and *Bartlett*'s description [16] of possible mechanisms to account for the outcome of these reactions remains a definitive analysis. Clearly, in the cascade *radical-mediated* cyclisations described in this study, and elsewhere, the Me substituents on the participating C=C bonds exercise a controlling and complementary stereoelectronic effect on the stereochemical outcome of the reactions. Indeed, polyene precursors without Me substitution on the participating C=C bonds react predictably *via* the preferred 5-*exo*-trig mode of radical cyclisation, leading to five- rather than six-ring fused systems. No physical organic studies have been made on the aforementioned radical cyclisations. Any rational mechanistic analysis will need to take account of the very different 6-*endo*-trig *acyl* radical ring A cyclisation [17], followed by the consecutive 6-*endo*-trig *alkyl* radical ring-B/C/D/E/F/G-forming processes. Similar to electrophilic polyene cyclisations, there are several mechanistic options available including a concerted processs involving significant π-stacking using a fully chair-chair transition state, or a step-wise process in which each ring-forming process has a degree of reversibility. There are other factors to consider, clearly, when the double bonds are substituted by radical-stabilising groups, *e.g.*, CO_2Et, instead of Me, *i.e.*, **3** → **4** which lead to other stereochemical outcomes. It may also be significant that the cascade cyclisation of **5c** leading to **25** 'pauses' after tetracyclisation for sufficient time to allow the isolation of significant amounts of the tetracyclic ketone **27**. Perhaps the radical cyclisations from **1** and **5a**–**c** are a mixture of reversible and concerted processes, based on the geometrical restrictions imposed on the systems according to the level, *i.e.*, mono-, bi-, tri-, tetra- *etc.*, of cyclisation as the cascade unfolds? Clearly, definitive answers to these important questions will only emerge following further detailed physical-organic studies of these novel and unprecedented radical-mediated cascades.

We thank the *EPSRC* for support of this work *via* Postdoctoral fellowships to *S. H.* and *P. S. N.*

Experimental Part

1. *General.* Abbreviations: AIBN: 2,2′-azobis(2-methylpropanenitrile), DMAP: 4-(dimethylamino)pyridine, DHP: 3,4-dihydro-2*H*-pyran, DMPU: 1,3-dimethyl-3,4,5,6-tetrahydropyrimidin-2(1*H*)-one, FC: flash chromatography, MsCl: methanesulfonyl chloride, NBS: *N*-bromosuccinimide, petrol: petroleum ether 40–60°, $TsOH \cdot H_2O$: *para*-toluenesulfonic acid monohydrate, PPTS: pyridinium *p*-toluenesulfonate, TsCl: *para*-toluenesulfonyl chloride. General experimental considerations have been detailed previously [4a].

2. *Preparation of Thioethers* **10**. *General Representative Procedure: (*E,E,E*)-3,7,11,15-Tetramethyl-1-(phenylthio)hexadeca-2,6,10,14-tetraene* (**10a**). BuLi (8.00 ml, 20.0 mmol, 2.5M in hexanes) was added dropwise over 10 min to a stirred soln. of geranylgeraniol **9a** [8] (5.81 g, 20.0 mmol) in THF (30 ml) at 0° to a Ph_3CH endpoint. The mixture was stirred at 0° for 5 min and then a soln. of TsCl (4.00 g, 21.0 mmol) in DMPU (10 ml) added dropwise over 10 min. The mixture was stirred at 0° for 3 h, then LiSPh (24 ml, 24 mmol, 1M in THF) was added and the reaction was brought to r.t. for 3 h before addition of 10% aq. soln. of NaOH (100 ml). The resulting mixture was extracted with Et_2O, and the combined org. extracts were dried ($MgSO_4$) and evaporated *in vacuo*. FC (Et_2O/petrol 1:99 → 1:19) gave **10a** (6.8 g, 89%). Colorless oil. IR (film): 3056, 2963, 2921, 2852, 1662, 1584, 1479, 1438, 1381, 1090, 1025, 736, 690. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.36 (*dd*, *J* = 1.1, 8.2, H–C(2), H–C(6) of Ph); 7.28 (app. *t*, *J* = 8.2, H–C(3), H–C(5) of Ph); 7.21 (*m*, H–C(4) of Ph); 5.34 (*t*, *J* = 7.6, C=C*H*(CH_2S); 5.13–5.11 (*m*, 3 C=CH); 3.57 (*d*, *J* = 7.6, CH_2S); 2.09–1.98 (*m*, 12 H); 1.70 (*s*, Me); 1.62

(*s*, 2 Me); 1.61 (*s*, Me); 1.61 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 139.9 (*s*); 136.8 (*s*); 135.3 (*s*); 134.9 (*s*); 131.2 (*s*); 129.8 (2*d*); 128.7 (2*d*); 126.0 (*d*); 124.2 (*d*); 124.2 (*d*); 123.8 (*d*); 119.2 (*d*); 39.71 (*t*); 39.66 (*t*); 39.6 (*t*); 32.2 (*t*); 26.8 (*t*); 26.6 (*t*); 26.4 (*t*); 25.7 (*q*); 17.7 (*q*); 16.0 (3*q*). EI-MS: 382.2698 (M^+, $C_{26}H_{38}S^+$; calc. 382.2694).

*(*E,E,E,E,E*)-3,7,11,15,19,23-Hexamethyl-1-(phenylthio)tetracosa-2,6,10,14,18,22-hexaene* (**10b**). BuLi (2.75 ml, 6.88 mmol, 2.5M in hexanes), the hexaprenol **9b** (2.67 g, 6.26 mmol), TsCl (1.43 g, 7.50 mmol) and LiSPh (8.75 ml, 8.75 mmol, 1M in THF) were reacted according to the general procedure to give **10b** (3.02 g, 93%). Colorless oil. IR (film): 3055, 2962, 2922, 2852, 1663, 1584, 1479, 1438, 1382, 1229, 1154, 1090, 1025, 737, 690. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.36 (*dd*, *J* = 1.4, 7.5, H–C(2), H–C(6) of Ph); 7.30–7.26 (*m*, H–C(3), H–C(5) of Ph); 7.21 (*tt*, *J* = 1.4, 7.2, H–C(4) of Ph); 5.33 (*t*, *J* = 7.6, C=C*H*CH$_2$S); 5.15–5.10 (*m*, 5 C=CH); 3.56 (*d*, *J* = 7.6, CH$_2$S); 2.11–2.00 (*m*, 20 H); 1.70 (*s*, Me); 1.62 (*s*, 5 Me); 1.60 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 139.9 (*s*); 136.8 (*s*); 135.3 (*s*); 134.92 (*s*); 134.88 (*s*); 134.8 (*s*); 131.2 (*s*); 130.0 (*d*); 129.8 (2*d*); 129.0 (*d*); 128.7 (2*d*); 125.9 (*d*); 124.4 (*d*); 124.2 (*d*); 123.7 (*d*); 119.2 (*d*); 39.7 (3*t*); 39.6 (*t*); 33.3 (*t*); 32.2 (*t*); 26.8 (*t*); 26.7 (*t*); 26.6 (2*t*); 26.4 (*t*); 25.7 (*q*); 17.7 (*q*); 16.0 (5*q*). EI-MS: 518.3936 (M^+, $C_{36}H_{54}S^+$; calc. 518.3947).

3. *Alkylation of Thioethers Leading to* **12**. *General Representative Procedure: (*E,E,E,E,E*)-1-(Benzyloxy)-3,7,11,15,19,23-hexamethyl-9-(phenylthio)tetracosa-2,6,10,14,18,22-hexaene* (**12a**). BuLi (5.0 ml, 12.50 mmol, 2.5M in hexanes) was added dropwise over 10 min to a stirred soln. of **10a** (4.67 g, 12.22 mmol) in THF (60 ml) at –78°. The mixture was stirred at this temp. for 4 h, and then a soln. of the allylic bromide **11** [9] (4.35 g, 13.44 mmol) in THF (10 ml) was added dropwise over 10 min. The resulting mixture was stirred at –78° for a further 3 h, and then a 1:1 mixture of MeOH/Et_2O was added and the reaction allowed to attain r.t. The mixture was diluted with H_2O and extracted with Et_2O. The org. extracts were combined, washed with brine, dried ($MgSO_4$) and the solvent evaporated *in vacuo*. FC (Et_2O/petrol 1:19 → 1:9) gave **12a** (6.43 g, 84%). Colorless oil. IR (film): 2971, 2921, 2853, 1664, 1583, 1477, 1438, 1381, 1118, 1089, 1068, 1026, 737, 694. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.42 (*dd*, *J* = 2.2, 7.9); 7.36–7.33 (*m*, 4 H); 7.31–7.24 (*m*, 4 H); 5.41 (*t*, *J* = 6.5, C=C*H*CH$_2$O); 5.19–5.02 (*m*, 4 C=CH); 5.01 (*d*, *J* = 9.8, C=C*H*CHS); 4.51 (*s*, OC*H*$_2$Ph); 4.05–4.02 (*m*, CHS); 4.03 (*d*, *J* = 6.5, C=CHC*H*$_2$O); 2.41–1.95 (*m*, 18 H); 1.70 (*s*, Me); 1.65 (*s*, Me); 1.62 (*s*, Me); 1.61 (*s*, 2 Me); 1.60 (*s*, Me); 1.36 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 140.3 (*s*); 138.5 (*s*); 137.7 (*s*); 135.1 (*s*); 135.0 (*s*); 134.9 (*s*); 133.7 (2*d*); 132.3 (*s*); 131.3 (*s*); 128.4 (2*d*); 128.3 (2*d*); 127.8 (2*d*); 127.5 (*d*); 127.1 (*d*); 126.8 (*d*); 125.8 (*d*); 124.4 (*d*); 124.2 (*d*); 124.0 (*d*); 120.8 (*d*); 72.0 (*t*); 66.6 (*t*); 45.9 (*d*); 45.5 (*t*); 39.7 (2*t*); 39.6 (*t*); 39.4 (*t*); 26.7 (*t*); 26.6 (2*t*); 26.4 (*t*); 25.7 (*q*); 17.7 (*q*); 16.5 (*q*); 16.2 (*q*); 16.1 (*q*); 16.0 (2*q*). EI-MS: 624.4339 (M^+, $C_{43}H_{60}OS^+$; calc. 624.4365).

*(*E,E,E,E,E,E,E*)-1-(Benzyloxy)-3,7,11,15,19,23,27,31-octamethyl-9-(phenylthio)dotriaconta-2,6,10,14,18,22,26,30-octaene* (**12b**). BuLi (2.50 ml, 5.00 mmol, 2.5M in hexanes), **10b** (2.47 g, 4.76 mmol) and **11** (1.85 g, 5.71 mmol) were reacted according to the general procedure to give **12b** (2.83 g, 78%). Colorless oil. IR (film): 2964, 2918, 2852, 1665, 1583, 1494, 1478, 1438, 1381, 1089, 1068, 1026, 910, 734, 696. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.41 (*dd*, *J* = 2.8, 6.6, 2 H); 7.36–7.34 (*m*, 4 H); 7.30–7.24 (*m*, 4 H); 5.42 (*t*, *J* = 6.6, C=C*H*CH$_2$O); 5.18–5.10 (*m*, 6 C=CH); 5.02 (*d*, *J* = 10.1, C=C*H*CHS); 4.52 (*s*, OC*H*$_2$Ph); 4.06–4.02 (*m*, CHS); 4.03 (*d*, *J* = 6.6, C=CHC*H*$_2$O); 2.38–1.91 (*m*, 26 H); 1.70 (*s*, Me); 1.65 (*s*, Me); 1.62 (*s*, 5 Me); 1.37 (*s*, Me); 1.36 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 140.3 (*s*); 138.5 (*s*); 137.7 (*s*); 135.0 (*s*); 134.9 (*s*); 134.8 (2*s*); 133.7 (2*d*); 132.3 (2*s*); 131.6 (*s*); 128.4 (2*d*); 128.3 (*d*); 127.8 (2*d*); 127.5 (*d*); 127.1 (*d*); 126.8 (*d*); 125.8 (*d*); 124.4 (2*d*); 124.2 (*d*); 124.2 (*d*); 124.0 (*d*); 120.8 (2*d*); 72.0 (*t*); 66.6 (*t*); 45.9 (*d*); 45.5 (*t*); 39.7 (5*t*); 39.6 (*t*); 39.4 (*t*); 26.74 (*t*); 26.68 (2*t*); 26.6 (*t*); 26.3 (*t*); 25.7 (*q*); 17.7 (*q*); 16.5 (*q*); 16.2 (*q*); 16.1 (*q*); 16.0 (4*q*).

4. *Reduction of Alkylated Thioethers Leading to* **9**. *General Representative Procedure: (*E,E,E,E,E*)-3,7,11,15,19,23-Hexamethyltetracosa-2,6,10,14,18,22-hexaen-1-ol* (**9b**). Excess Li wire (*ca.* 300 mg, 43.23 mmol) was added in a single portion to a stirred soln. of **12a** (3.04 g, 4.87 mmol) in THF/$EtNH_2$ 1:1 (80 ml) at –78°. The mixture was stirred vigorously at –78° until it attained a permanent blue colouration (2 h) after which point it was stirred for an additional 10 min. Excess Li wire was removed physically from the mixture, and a soln. of hex-1-yne in THF was then added to the reaction until the blue colour was totally dissipated. MeOH (5 ml) was introduced into the mixture, which was then allowed to attain r.t. before sat. aq. NH_4Cl was added. The resulting mixture was extracted with Et_2O, the org. extracts were combined, washed with brine, dried ($MgSO_4$), and the solvent was evaporated *in vacuo*. FC (Et_2O/petrol 1:9 → 1:1) gave **9b** (1.95 g, 94%; 12:1 mixture of undetermined olefin isomers). Data for the major isomer: Colorless oil. IR (film): 3310, 2963, 2920, 2853, 1667, 1446, 1381, 1150, 1103, 1101, 734. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.43 (*tt*, *J* = 1.1, 7.0, C=C*H*CH$_2$O); 5.14–5.08 (*m*, 5 C=CH); 4.16 (*d*, *J* = 7.0, CH$_2$O); 2.16–2.05 (*m*, 12 H); 2.01–1.98 (*m*, 8 H); 1.69 (*s*, 2 Me); 1.61 (*s*, 5 Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 139.8 (*s*); 135.4 (*s*); 135.0 (*s*); 134.90 (*s*); 134.86 (*s*); 131.2 (*s*); 124.4 (*d*); 124.2 (2*d*); 124.1 (*d*); 123.7 (*d*); 123.3 (*d*); 59.4 (*t*); 39.7 (5*t*); 39.5 (*t*); 26.7 (*t*); 26.6 (2*t*); 26.3 (*t*); 25.7 (*q*); 17.7 (*q*); 16.3 (*q*); 16.0 (4*q*). EI-MS: 426.3852 (M^+, $C_{30}H_{50}O^+$; calc. 426.3862).

*(*E,E,E,E,E,E,E*)-3,7,11,15,19,23,27,31-Octamethyldotriaconta-2,6,10,14,18,22,26,30-octaen-1-ol* (**9c**). Li wire (*ca.* 200 mg, 28.82 mmoL) and **12b** (2.36 g, 3.10 mmol) were reacted according to the general procedure to give **9c** (1.50 g, 86%; 9:1 mixture of undetermined olefin isomers). Data for major isomer: Colorless oil. IR (film): 3360, 2919, 2852, 1666, 1445, 1382, 1151, 1103, 1018, 838. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.43 (*t*, *J* = 7.0, C=C*H*CH$_2$O); 5.14–5.08 (*m*, 7 C=CH); 4.16 (*d*, *J* = 7.0, CH$_2$O); 2.16–2.05 (*m*, 14 H); 2.01–1.98 (*m*, 14 H); 1.69 (*s*, 2 Me); 1.61 (*s*, 7 Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 139.8 (*s*); 135.4 (*s*); 135.0 (*s*); 134.89 (2*s*); 134.87 (*s*); 134.8 (*s*); 131.2 (*s*); 124.4 (2*d*); 124.3 (3*d*); 124.1 (*d*); 123.8 (*d*); 123.3 (*d*); 59.4 (*t*); 39.7 (5*t*); 39.5 (*t*); 26.7 (*t*); 26.67 (3*t*); 26.64 (3*t*); 26.3 (*t*); 25.7 (*q*); 17.7 (*q*); 16.3 (*q*); 16.0 (6*q*). EI-MS: 562.5119 (M^+, $C_{40}H_{66}O^+$; calc. 562.5114).

5. *Acetylation of Prenols. General Representative Procedure: (*E,E,E*)-3,7,11,15-Tetramethylhexadeca-2,6,10,14-tetraenyl Ethanoate* (**13a**). Ac$_2$O (779 µl, 843 mg, 8.26 mmol) was added dropwise over 2 min to a stirred soln. of **9a** [8] (2.18 g, 7.50 mmol), DMAP (92 mg, 0.75 mmol) and Et$_3$N (1.25 ml, 908 mg, 8.97 mmol) in CH_2Cl_2 (30 ml) at 0°. The mixture was allowed to warm to r.t. over 2 h and then stirred for a further 4 h before the addition of sat. brine. The mixture was extracted with Et$_2$O, the org. extracts were combined, dried (MgSO$_4$) and evaporated *in vacuo*. FC (Et$_2$O/petrol 1:4) gave **13a** (2.37 g, 95%). Colorless oil. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.34 (*t*, *J* = 7.1, C=C*H*CH$_2$O); 5.11–5.09 (*m*, 3 C=CH); 4.59 (*d*, *J* = 7.1, CH$_2$O); 2.14–2.03 (*m*, 8 H); 2.05 (*s*, Ac); 2.01–1.95 (*m*, 4 H); 1.71 (*s*, Me); 1.68 (*s*, Me); 1.60 (*s*, 3 Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 170.8 (*s*); 142.0 (*s*); 135.5 (*s*); 134.8 (*s*); 131.0 (*s*); 124.3 (*d*); 124.1 (*d*); 123.5 (*d*); 118.2 (*d*); 61.2 (*t*); 39.60 (*t*); 39.57 (*t*); 39.4 (*t*); 26.6 (*t*); 26.5 (*t*); 26.1 (*t*); 25.5 (*q*); 20.8 (*q*); 17.5 (*q*); 16.3 (*q*); 15.9 (2*q*).

*(*E,E,E,E,E*)-3,7,11,15,19,23-Hexamethyltetracosa-2,6,10,14,18,22-hexaenyl Ethanoate* (**13b**). Ac$_2$O (233 mg, 2.28 mmol), **9b** (0.81 g, 1.9 mmol), DMAP (23 mg, 0.19 mmol) and Et$_3$N (0.54 ml, 390 mg, 3.85 mmol) were reacted according to the general procedure to give **13b** (0.88 g, 99%) as a mixture of olefin isomers. Further chromatography on silica gel (25 g) impregnated with 10% AgNO$_3$ (AcOEt/petrol 1:9 → 2:1) gave isomerically pure **13b** (760 mg). Colorless oil. IR (film): 2922, 1742, 1446, 1381, 1230, 1022. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.35 (*m*, C=C*H*CH$_2$O); 5.12–5.09 (*m*, 5 C=C*H*); 4.60 (*d*, *J* = 7.0, CH$_2$O); 2.10–1.96 (*m*, 20 H); 2.04 (*s*, Ac); 1.71 (*s*, Me); 1.69 (*s*, Me); 1.61 (*s*, 5 Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 171.0 (*s*); 142.2 (*s*); 135.4 (*s*); 134.9 (*s*); 134.8 (2*s*); 131.2 (*s*); 124.3 (*d*); 124.2 (2*d*); 124.1 (*d*); 123.5 (*d*); 118.2 (*d*); 61.3 (*t*); 39.6 (4*t*); 39.5 (*t*); 26.7 (*t*); 26.6 (2*t*); 25.9 (*t*); 25.6 (*t*); 21.0 (*q*); 17.6 (*q*); 16.4 (*q*); 15.9 (5*q*). EI-MS: 468.3943 (M^+, $C_{32}H_{52}O_2^+$; calc. 468.3970). Anal. calc. for $C_{32}H_{52}O_2$: C 82.0, H 11.2; found: C 81.8, H 11.2.

*(*E,E,E,E,E,E,E*)-3,7,11,15,19,23,27,31-Octamethyldotriaconta-2,6,10,14,18,22,26,30-octaenyl Ethanoate* (**13c**). Ac$_2$O (80 µl, 86 mg, 0.847 mmol), **9c** (402 mg, 0.713 mmol), DMAP (9 mg, 0.072 mmol) and Et$_3$N (120 µl, 87 mg, 0.861 mmol) were reacted according to the general procedure to give **13c** (421 mg, 98%) as a mixture of olefin isomers. Further chromatography on silica gel (25 g) impregnated with 10% AgNO$_3$ (AcOEt/petrol 1:9 → 3:1) gave isomerically pure **13c** (309 mg). Colorless oil. IR (film): 2963, 2920, 2852, 1741, 1666, 1444, 1382, 1365, 1232, 1023, 910, 735. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.35 (*t*, *J* = 7.0, C=C*H*CH$_2$O); 5.12 (*t*, *J* = 6.3, 7 C=CH); 4.59 (*d*, *J* = 7.0, CH$_2$O); 2.11–2.05 (*m*, 14 H); 2.09 (*s*, Ac); 2.01–1.98 (*m*, 14 H); 1.71 (*s*, Me); 1.69 (*s*, Me); 1.61 (*s*, 7 Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 171.1 (*s*); 142.3 (*s*); 135.5 (*s*); 135.0 (*s*); 134.9 (4*s*); 131.2 (*s*); 124.4 (*d*); 124.2 (4*d*); 124.1 (*d*); 123.6 (*d*); 118.2 (*d*); 61.4 (*t*); 39.7 (6*t*); 39.5 (*t*); 26.74 (*t*); 26.68 (3*t*); 26.65 (2*t*); 26.2 (*t*); 25.7 (*q*); 21.0 (*q*); 17.7 (*t*); 16.5 (*q*); 16.0 (6*q*). EI-MS: 544.5006 ([*M* – MeCO$_2$H]$^+$, $C_{40}H_{64}^+$; calc. 544.5008).

6. *Epoxidation with NBS and K_2CO_3 Leading to* **14**. *General Representative Procedure: (*E,E,E*)-14,15-Epoxy-3,7,11,15-tetramethylhexadeca-2,6,10-trien-1-ol* (**14a**). NBS (1.18 g, 6.63 mmol) was added in small portions over 20 min to a stirred soln. of **13a** (2.05 g, 6.17 mmol) in THF (150 ml) and H$_2$O (75 ml) at 0°. The mixture was stirred at 0° for 5 h, and then the bulk of the THF was removed *in vacuo*. The resulting mixture was extracted with Et$_2$O, the combined organic extracts were dried (MgSO$_4$) and then evaporated *in vacuo*. The residue was dissolved in MeOH (100 ml), and solid K$_2$CO$_3$ (6 g, 43.6 mmol) was then added in a single portion. The resulting suspension was stirred vigourously for 16 h, filtered, and the MeOH removed *in vacuo*. H$_2$O was added to the resulting residue, and the mixture was extracted with Et$_2$O. The extracts were combined, dried (MgSO$_4$) and evaporated *in vacuo*. FC (Et$_2$O/petrol 1:1) to leave **14a** (1.19 g, 63%). Colorless oil. ^{1}H-NMR (270 MHz, $CDCl_3$): 5.32 (*t*, *J* = 7.1, C=C*H*CH$_2$O); 5.13 (*t*, *J* = 6.8, C=CH); 5.07 (*t*, *J* = 6.8, C=CH); 4.55 (*d*, *J* = 7.1, CH$_2$O); 2.67 (*t*, *J* = 6.2, CHO); 2.12–1.94 (*m*, 12 H); 1.68 (*s*, Me); 1.59 (*s*, Me); 1.57 (*s*, Me); 1.27 (*s*, Me); 1.23 (*s*, Me). ^{13}C-NMR (67.5 MHz, $CDCl_3$): 139.1 (*s*); 135.0 (*s*); 133.9 (*s*); 124.7 (*d*); 123.8 (*d*); 123.4 (*d*); 64.1 (*d*); 59.1 (*t*); 58.3 (*s*); 39.45 (*t*); 39.42 (*t*); 36.2 (*t*); 27.3 (*t*); 26.4 (*t*); 26.2 (*t*); 24.8 (*q*); 18.6 (*q*); 16.1 (*q*); 15.9 (2*q*).

*(*E,E,E,E,E*)-22,23-Epoxy-3,7,11,15,19,23-hexamethyltetracosa-2,6,10,14,18-pentaen-1-ol* (**14b**). According to the general procedure, NBS (0.70 g, 3.93 mmol) and **13b** (1.8 g, 3.85 mmol) were reacted in THF/H$_2$O, and the resulting bromohydrin was treated with K$_2$CO$_3$ (8 g, 57.89 mmol) to give **14b** (0.81 g, 48%). Colorless oil. IR

(film) 3426, 2921, 1666, 1447, 1379, 1249, 1121, 1009, 872, 674. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.40 (*t*, *J* = 7.2, C=C*H*CH_2O); 5.17–5.08 (*m*, 4 C=CH); 4.15 (*d*, *J* = 6.6, CH_2O); 2.72 (*t*, *J* = 6.3, CHO); 2.15–1.95 (*m*, 21 H); 1.67 (*s*, Me); 1.61 (*s*, Me); 1.59 (*s*, 3 Me); 1.30 (*s*, Me); 1.25 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 139.5 (*s*); 135.3 (*s*); 134.9 (*s*); 134.7 (*s*); 133.9 (*s*); 124.8 (*d*); 124.3 (*d*); 124.1 (*d*); 123.7 (*d*); 123.3 (*d*); 64.2 (*d*); 59.3 (*t*); 58.3 (*s*); 39.6 (2*t*); 39.5 (*t*); 39.4 (*t*); 36.2 (*t*); 27.4 (*t*); 26.7 (*t*); 26.6 (2*t*); 26.2 (*t*); 24.8 (*q*); 18.7 (*q*); 16.2 (*q*); 15.9 (4*q*). FAB-MS: 465.3609 ([*M* + Na]$^+$, $C_{30}H_{50}NaO_2^+$; calc. 465.3711). Anal. calc. for $C_{30}H_{50}O_2$: C 81.4, H 11.4; found: C 81.1, H 11.5.

*(*E,E,E,E,E,E,E*)-30,31-Epoxy-3,7,11,15,19,23,27,31-octamethyldotriaconta-2,6,10,14,18,22,26-heptaen-1-ol* (**14c**). According to the general procedure, NBS (87 mg, 0.490 mmol) and **13c** (270 mg, 0.446 mmol) were reacted in THF/H_2O and the resulting bromohydrin treated with K_2CO_3 (677 mg, 4.90 mmol) to give recovered **9c** (43 mg) and **14c** (137 mg, 53%). Colorless oil. IR ($CHCl_3$): 3350, 2925, 2853, 1665, 1457, 1380, 1088, 980. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.43 (*dt*, *J* = 1.2, 6.9, C=C*H*CH_2OH); 5.18–5.10 (*m*, 6 C=CH); 4.15 (*d*, *J* = 6.9, CH_2O); 2.71 (*t*, *J* = 6.3, CHO); 2.18–1.97 (*m*, 28 H); 1.69 (*s*, Me); 1.62 (*s*, Me); 1.61 (*s*, 2 Me); 1.59 (*s*, 3 Me); 1.31 (*s*, Me); 1.27 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 139.7 (*s*); 135.3 (*s*); 135.0 (*s*); 134.9 (*s*); 134.8 (*s*); 134.7 (*s*); 133.9 (*s*); 124.9 (*d*); 124.3 (*d*); 124.23 (*d*); 124.20 (*d*); 124.1 (*d*); 123.7 (*d*); 123.3 (*d*); 64.2 (*d*); 59.3 (*s*); 58.3 (*t*); 39.7 (3*t*); 39.6 (*t*); 39.5 (*t*); 36.3 (*t*); 27.4 (*t*); 26.7 (3*t*); 26.6 (3*t*); 26.3 (*t*); 24.9 (*q*); 18.7 (*q*); 16.2 (*q*); 16.0 (6*q*).

7. *Epoxide Opening and Cleavage to* **15**. *General Representative Procedure: (*E,E,E*)-4,8,12-Trimethyl-4-[(tetrahydro-2*H*-pyran-2-yl)oxy]tetradeca-4,8,12-trien-1-ol* (**15a**). A soln. of $HIO_4 \cdot 2\,H_2O$ (900 mg, 3.66 mmol) in H_2O (4 ml) was added to a stirred soln. of **14a** (1.02 g, 3.33 mmol) in THF (12 ml) and H_2O (2 ml) at 0°. The mixture was allowed to warm to r.t. over 1 h and then stirred for a further 2 h before addition of H_2O and extraction with Et_2O. The combined org. extracts were washed successively with sat. aq. $NaHCO_3$, H_2O and brine, dried ($MgSO_4$) and then evaporated *in vacuo*. The resulting residue was dissolved in CH_2Cl_2 (20 ml), and then DHP (440 µl, 405 mg, 4.81 mmol) and PPTS (80 mg, 0.32 mmol) were added. The mixture was stirred at r.t. for 8 h before being diluted with sat. aq. $NaHCO_3$ and extracted with Et_2O. The org. extracts were combined, dried ($MgSO_4$) and evaporated *in vacuo*. The residue was then dissolved in Et_2O (10 ml), and $NaBH_4$ (182 mg, 4.81 mmol) and MeOH (200 µl) were added. The mixture was stirred at r.t. for 16 h, diluted with H_2O and extracted with Et_2O. The combined org. extracts were dried ($MgSO_4$), and the solvent was removed *in vacuo*. FC (Et_2O/petrol 1:9 → 1:1) gave **15a** (752 mg, 67%). Colorless oil. IR (film): 3467, 2937, 2868, 1666, 1441, 1383, 1353, 1322, 1261, 1200, 1183, 1117, 1076, 1053, 1023. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.35 (*dd*, *J* = 6.4, 7.4, C=C*H*CH_2O); 5.16–5.08 (*m*, 2 C=CH); 4.62 (*t*, *J* = 3.4, OCHO); 4.23 (*dd*, *J* = 6.4, 11.9, 1 H, C=CHC*H*$_2$O); 4.03 (*dd*, *J* = 7.4, 11.9, 1 H, C=CHCH_2O); 3.92–3.86 (*m*, 1 H); 3.61 (*t*, *J* = 6.4, CH_2OH); 3.53–3.48 (*m*, 1 H); 2.16–1.96 (*m*, 10 H); 1.87–1.79 (*m*, 2 H); 1.75–1.53 (*m*, 6 H); 1.67 (*s*, Me); 1.60 (*s*, Me); 1.59 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 140.2 (*s*); 135.0 (*s*); 134.6 (*s*); 124.6 (*d*); 124.0 (*d*); 120.5 (*d*); 97.7 (*d*); 63.6 (*t*); 62.7 (*t*); 62.2 (*t*); 39.5 (2*t*); 35.9 (*t*); 30.7 (*t*); 30.6 (*t*); 26.4 (*t*); 26.2 (*t*); 25.4 (*t*); 19.5 (*t*); 16.3 (*q*); 15.9 (*q*); 15.8 (*q*). EI-MS: 248.2143 ([*M* – $C_5H_{10}O_2$ (THP-OH)]$^+$, $C_{17}H_{28}O^+$; calc. 248.2140).

*(*E,E,E,E,E*)-4,8,12,16,20-Pentamethyl-22-[(tetrahydro-2*H*-pyran-2-yl)oxy]docosa-4,8,12,16,20-pentaen-1-ol* (**15b**). According to the general procedure, $HIO_4 \cdot H_2O$ (0.37 g, 1.62 mmol) and **14b** (600 mg, 1.36 mmol) were reacted, and the resulting hydroxy aldehyde was protected with DHP (174 µl, 160 mg, 1.84 mmol) and PPTS (46 mg, 0.189 mmol). Reduction of the resulting aldehyde with $NaBH_4$ (23 mg, 0.61 mmol) and MeOH (300 µl) in Et_2O gave **15a** (437 mg, 66%). Colorless oil. IR (film): 3392, 2921, 1666, 1442, 1383, 1117, 1023. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.35 (*dd*, *J* = 6.5, 7.5, C=C*H*CH_2O); 5.14–5.09 (*m*, 4 C=CH); 4.64 (*m*, OCHO); 4.25 (*dd*, *J* = 6.5, 12.0, 1 H, C=CHC*H*$_2$O); 4.03 (*dd*, *J* = 7.5, 12.0, 1 H, C=CHCH_2O); 3.92–3.86 (*m*, 1 H); 3.63 (*m*, CH_2OH); 3.52–3.47 (*m*, 1 H); 2.14–1.95 (*m*, 18 H); 1.90–1.71 (*m*, 4 H); 1.68 (*s*, Me); 1.60 (*s*, 4 Me); 1.56–1.43 (*m*, 4 H). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 140.2 (*s*); 135.2 (*s*); 134.9 (*s*); 134.7 (*s*); 134.5 (*s*); 124.7 (*d*); 124.3 (*d*); 124.1 (*d*); 123.8 (*d*); 120.4 (*d*); 97.7 (*d*); 63.6 (*t*); 62.7 (*t*); 62.2 (*t*); 39.6 (2*t*); 39.6 (2*t*); 35.9 (*t*); 30.6 (2*t*); 26.6 (2*t*); 26.5 (*t*); 25.4 (*t*); 19.5 (*t*); 16.4 (*q*); 16.0 (2*q*); 15.9 (*q*); 15.8 (*q*). FAB-MS: 509.3984 ([*M* + Na]$^+$; $C_{32}H_{54}NaO_3^+$; calc. 509.3974). Anal. calc. for $C_{32}H_{54}O_3$: C 79.0, H 11.2; found: C 78.9, H 11.4.

*(*E,E,E,E,E,E,E,E*)-4,8,12,16,20,24,28-Heptamethyl-30-[(tetrahydro-2*H*-pyran-2-yl)oxy]triaconta-4,8,12,16,20,24,28-heptaen-1-ol* (**15c**). According to the general procedure $HIO_4 \cdot 2\,H_2O$ (72 mg, 0.293 mmol) and **14c** (120 mg, 0.207 mmol) were reacted, and the resulting hydroxy aldehyde protected with DHP (29 µl, 27 mg, 0.317 mmol) and PPTS (4 mg, 0.016 mmol). Reduction of the resulting aldehyde with $NaBH_4$ (12 mg, 0.317 mmol) and MeOH (100 µl) in Et_2O gave **15c** (72 mg, 56%). Colorless oil. IR ($CHCl_3$): 3620, 2926, 2852, 1665, 1602, 1442, 1384, 1116, 1074, 1052, 1021, 906. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.38–5.35 (*m*, C=C*H*CH_2O); 5.17–5.10 (*m*, 6 C=CH); 4.63 (*t*, *J* = OCHO); 4.24 (*dd*, *J* = 6.9, 11.8, 1 H, C=CHC*H*$_2$O); 4.03 (*dd*, *J* = 7.4, 11.8, 1 H, C=CHCH_2O); 3.93–3.86 (*m*, 1 H); 3.62 (*t*, *J* = 6.5, CH_2OH); 3.54–3.48 (*m*, 1 H); 2.11–1.96 (*m*, 26 H); 1.72–1.66 (*m*, 2 H); 1.68 (*s*, Me); 1.61 (*s*, Me); 1.61–1.51 (*m*, 6 H); 1.60 (*s*, 5 Me). ^{13}C-NMR (90.6 MHz,

$CDCl_3$): 140.3 (*s*); 135.2 (*s*); 134.91 (*s*); 134.86 (*s*); 134.8 (*s*); 134.7 (*s*); 134.5 (*s*); 124.7 (*d*); 124.3 (*d*); 124.22 (*d*); 124.20 (*d*); 124.1 (*d*); 123.8 (*d*); 120.5 (*d*); 97.7 (*d*); 63.6 (*t*); 62.7 (*t*); 62.2 (*t*); 39.7 (4*t*); 39.6 (3*t*); 35.9 (*t*); 30.67 (*t*); 30.66 (*t*); 26.6 (3*t*); 26.5 (*t*); 26.3 (*t*); 25.5 (*t*); 19.6 (*t*); 16.4 (*q*); 16.0 (4*q*); 15.9 (*q*); 15.8 (*q*). EI-MS: 520.4636 ([$M - C_5H_{10}O_2$ (THP-OH)]$^+$, $C_{37}H_{60}O^+$; calc. 520.4644).

8. *Formation of Nitrite* **16**. *General Representative Procedure: (*E,E,E*)-5,9,13-Trimethyl-15-[(tetrahydro-2*H*-pyran-2-yl)oxy]pentadeca-5,9,13-trienenitrile* (**16a**). MsCl (135 µl, 201 mg, 1.75 mmol) was added dropwise to a stirred soln. of **15a** (512 mg, 1.46 mmol) and Et_3N (305 µl, 222 mg, 2.19 mmol) in CH_2Cl_2 (8 ml) at 0°. The mixture was stirred at 0° for 2 h, diluted with H_2O and extracted with CH_2Cl_2. The combined org. extracts were then dried ($MgSO_4$), and the solvent was evaporated *in vacuo*. The resulting residue was dissolved in DMSO (8 ml), treated with NaCN (358 mg, 7.31 mmol) and the mixture stirred at 60° for 18 h. The mixture was allowed to cool, diluted with H_2O and extracted with Et_2O. The combined org. extracts were washed with brine, dried ($MgSO_4$) and then evaporated *in vacuo*. FC (Et_2O/petrol 1:4) gave **16a** (467 mg, 89%). Colorless oil. IR ($CHCl_3$): 2941, 2871, 2852, 2248, 1667, 1452, 1441, 1384, 1353, 1200, 1138, 1117, 1077, 1052, 1023. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.38 (*dd*, *J* = 6.4, 7.4, C=C*H*CH_2O); 5.18 (*t*, *J* = 6.9, C=CH); 5.11 (*t*, *J* = 6.7, C=CH); 4.63 (*t*, *J* = 3.5, OCHO); 4.24 (*dd*, *J* = 6.4, 11.9, C=CHCH_2O); 4.03 (*dd*, *J* = 7.4, 11.9, 1 H, C=CHCH_2O); 3.92–3.87 (*m*, 1 H); 3.54–3.47 (*m*, 1 H); 2.28 (*t*, *J* = 7.2, CH_2CN); 2.14–1.97 (*m*, 10 H); 1.86–1.83 (*m*, 1 H); 1.81–1.74 (*m*, 3 H); 1.68 (*s*, Me); 1.65–1.50 (*m*, 4 H); 1.60 (*s*, Me); 1.59 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 140.1 (*s*); 134.9 (*s*); 132.2 (*s*); 126.5 (*d*); 124.1 (*d*); 120.6 (*d*); 119.8 (*s*); 97.8 (*d*); 63.6 (*t*); 62.3 (*t*); 39.6 (*t*); 39.5 (*t*); 38.1 (*t*); 30.7 (*t*); 26.5 (*t*); 26.2 (*t*); 25.5 (*t*); 23.3 (*t*); 19.6 (*t*); 16.4 (*q*); 16.2 (*t*); 15.9 (*q*); 15.6 (*q*). EI-MS: 257.2134 ([$M - C_5H_{10}O_2$ (THP-OH)]$^+$, $C_{18}H_{27}N^+$; calc. 257.2144).

*(*E,E,E,E,E*)-5,9,13,17,21-Pentamethyl-23-[(tetrahydro-2*H*-pyran-2-yl)oxy]tricosa-5,9,13,17,21-pentaenenitrile* (**16b**). MsCl (40 µl, 0.05 g, 0.45 mmol), **15b** (0.20 g, 0.41 mmol) and Et_3N (62 mg, 0.61 mmol) were reacted according to the general procedure, and the resulting crude methanesulfonate was treated with NaCN (150 mg, 3.06 mmol) to give **16b** (170 mg, 83%). Colorless oil. IR (film): 2922, 2241, 1666, 1441, 1383, 1120, 1116, 1076, 1023. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.35–5.31 (*m*, C=C*H*CH_2O); 5.16–5.14 (*m*, C=CH); 5.13–5.09 (*m*, 3 C=CH); 4.63 (*t*, *J* = 3.5, OCHO); 4.23 (*dd*, *J* = 6.3, 11.8, 1 H, C=CHCH_2O); 4.02 (*dd*, *J* = 7.5, 11.8, 1 H, C=CHCH_2O); 3.93–3.89 (*m*, 1 H); 3.52–3.48 (*m*, 1 H); 2.28 (*t*, *J* = 7.2, CH_2CN); 2.15–1.95 (*m*, 18 H); 1.88–1.70 (*m*, 4 H); 1.68 (*s*, Me); 1.60 (*s*, 4 Me); 1.57–1.49 (*m*, 4 H). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 140.2 (*s*); 135.2 (*s*); 134.8 (*s*); 134.5 (*s*); 132.1 (*s*); 126.6 (*d*); 124.4 (*d*); 124.2 (*d*); 123.8 (*d*); 120.5 (*d*); 119.7 (*s*); 97.7 (*d*); 63.6 (*t*); 62.2 (*t*); 39.6 (2*t*); 39.6 (*t*); 39.5 (*t*); 38.1 (*t*); 30.6 (*t*); 26.6 (*t*); 26.5 (*t*); 26.2 (*t*); 25.4 (2*t*); 23.3 (*t*); 19.6 (*t*); 16.4 (*q*); 16.1 (*t*); 16.0 (2*q*); 15.9 (*q*); 15.5 (*q*). EI-MS: 518.3883 ([$M + Na$]$^+$, $C_{33}H_{53}NNaO_2^+$; calc. 518.3974). Anal. calc. for $C_{33}H_{53}NO_2$: C 79.9, H 10.8, N 2.8; found: C 70.9, H 11.0.

*(*E,E,E,E,E,E,E*)-5,9,13,17,21,25,29-Heptamethyl-31-[(tetrahydro-2*H*-pyran-2-yl)oxy]hentriaconta-5,9,13,17,21,25,29-heptaenenitrile* (**16c**). MsCl (10 µl, 14.8 mg, 0.129 mmol), the alcohol **15c** (64 mg, 0.103 mmol) and Et_3N (21 µl, 15.2 mg, 0.151 mmol) were reacted according to the general procedure, and the resulting crude methanesulfonate treated with NaCN (50 mg, 1.02 mmol) to give **16c** (56 mg, 86%). Colorless oil. IR (film): 3003, 2926, 2852, 2248, 1666, 1453, 1383, 1356, 1116, 1075, 1021. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.37 (*dd*, *J* = 6.4, 7.4, C=C*H*CH_2O); 5.20–5.10 (*m*, 6 C=CH); 4.63 (*t*, *J* = 3.4, OCHO); 4.24 (*dd*, *J* = 6.4, 11.8, 1 H, C=CHCH_2O); 4.03 (*dd*, *J* = 7.4, 11.8, 1 H, C=CHCH_2O); 3.92–3.87 (*m*, 1 H); 3.53–3.48 (*m*, 1 H); 2.28 (*t*, *J* = 7.1, CH_2CN); 2.14–1.96 (*m*, 26 H); 1.88–1.81 (*m*, 2 H); 1.76 (app. *quint.* *J* = 7.1, C$H_2$$CH_2CN$); 1.69 (*s*, Me); 1.63–1.50 (*m*, 4 H); 1.61 (*s*, 6 CH_3). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 140.2 (*s*); 135.2 (*s*); 134.92 (*s*); 134.88 (*s*); 134.82 (*s*); 134.6 (*s*); 132.2 (*s*); 126.6 (*d*); 124.5 (*d*); 124.3 (*d*); 124.21 (*d*); 124.16 (*d*); 123.8 (*d*); 120.5 (*d*); 119.8 (*s*); 97.7 (*d*); 63.6 (*t*); 62.2 (*t*); 39.7 (4*t*); 39.6 (*t*); 39.5 (*t*); 38.2 (*t*); 30.7 (*t*); 26.7 (4*t*); 26.5 (*t*); 26.3 (*t*); 25.5 (*t*); 23.3 (*t*); 19.6 (*t*); 16.4 (*q*); 16.2 (*t*); 16.0 (4*q*); 15.9 (*q*); 15.6 (*q*). EI-MS: 529.4643 ([$M - C_5H_{10}O_2$ (THP-OH)]$^+$, $C_{38}H_{59}NO_2^+$; 529.4647).

9. *Nitrile Reduction Leading to* **17**. *General Representative Procedure: (*E,E,E*)-5,9,13-Trimethyl-15-[(tetrahydro-2*H*-pyran-2-yl)oxy]pentadeca-5,9,13-trienal* (**17a**). DIBAL-H (912 µl, 1.37 mmol) 1.5M in toluene) was added dropwise to a stirred soln. of **16a** (410 mg, 1.14 mmol) in toluene (8 ml) at −78°. The mixture was allowed to warm to 0° over 5 h before MeOH (2 ml) was carefully added, and then it was stirred for a further 10 min. A slurry of silica gel (5 g) in AcOEt (10 ml) was added and the resulting mixture stirred at r.t. for 1 h before being filtered. H_2O was added, the mixture was extracted with Et_2O, and the org. extracts were combined, dried ($MgSO_4$) and then evaporated *in vacuo*. FC (Et_2O/petrol 1:3) to leave **17a** (333 mg, 81%). Colorless oil. IR ($CHCl_3$): 2943, 2854, 1721, 1668, 1442, 1384, 1228, 1150, 1074, 1052, 1022. ^{1}H-NMR (360 MHz, $CDCl_3$): 9.77 (*t*, *J* = 1.7, CHO); 5.39–5.35 (*dd*, *J* = 6.4, 7.4, C=C*H*CH_2O); 5.11 (*t*, *J* = 6.3, 2 C=CH); 4.63 (*t*, *J* = 3.5, OCHO); 4.24 (*dd*, *J* = 6.4, 11.9, 1 H, C=CHCH_2O); 4.03 (*dd*, *J* = 7.4, 11.9, 1 H, C=CHCH_2O); 3.93–3.87 (*m*, 1 H); 3.54–3.49 (*m*, 1 H); 2.39 (*dt*, *J* = 1.7, 7.3, CH_2CHO); 2.15–1.97 (*m*, 10 H); 1.88–1.80 (*m*, 1 H); 1.78–1.72 (*m*, 3 H);

1.68 (*s*, Me); 1.62–1.50 (*m*, 4 H); 1.60 (*s*, Me); 1.59 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 202.7 (*d*); 140.2 (*s*); 135.1 (*s*); 133.7 (*s*); 125.5 (*d*); 124.0 (*d*); 120.6 (*d*); 97.8 (*d*); 63.6 (*t*); 62.3 (*t*); 43.2 (*t*); 39.61 (*t*); 39.58 (*t*); 38.8 (*t*); 30.7 (*t*); 26.5 (*t*); 26.3 (*t*); 25.5 (*t*); 20.2 (*t*); 19.6 (*t*); 16.4 (*q*); 16.0 (*q*); 15.7 (*q*). EI-MS: 260.2148 ([$M - C_5H_{10}O_2$ (THP-OH)]$^+$, $C_{18}H_{28}O^+$; calc. 260.2140).

*(*E,E,E,E,E*)-5,9,13,17,21-Pentamethyl-23-[(tetrahydro-2*H*-pyran-2-yl)oxy]tricosa-5,9,13,17,21-pentaenal* (**17a**). DIBAL-H (326 µl, 0.49 mmol, 1.5M in toluene) and **16b** (220 mg, 0.44 mmol) were reacted according to the general procedure to give **17b** (186 mg, 84%). Colorless oil. IR (film): 2924, 2713, 1727, 1666, 1441, 1383, 1261, 1200, 1117, 1076, 1023, 906, 869, 814. ^{1}H-NMR (360 MHz, $CDCl_3$): 9.77 (*t*, *J* = 1.6, CHO); 5.36 (*dd*, *J* = 6.3, 7.4, C=C*H*CH$_2$O); 5.13–5.09 (*m*, 4 C=CH); 4.63 (*t*, *J* = 3.4, OCHO); 4.21 (*dd*, *J* = 6.3, 11.9, 1 H, C=CHC*H*$_2$O); 4.05 (*dd*, *J* = 7.4, 11.9, 1 H, C=CHC*H*$_2$O); 3.94–3.90 (*m*, 1 H); 3.53–3.49 (*m*, 1 H); 2.46–2.42 (*m*, C*H*$_2$CHO); 2.14–1.95 (*m*, 18 H); 1.90–1.72 (*m*, 4 H); 1.68 (*s*, Me); 1.60 (*s*, 4 Me); 1.61–1.53 (*m*, 4 H). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 204.2 (*d*); 141.7 (*s*); 136.7 (*s*); 136.4 (*s*); 136.2 (*s*); 135.1 (*s*); 127.0 (*d*); 125.8 (*d*); 125.6 (*d*); 125.3 (*d*); 122.0 (*d*); 99.2 (*d*); 65.1 (*t*); 63.7 (*t*); 44.6 (*t*); 41.2 (2*t*); 41.1 (2*t*); 40.2 (*t*); 32.1 (*t*); 28.1 (2*t*); 28.0 (*t*); 27.7 (*t*); 26.9 (*t*); 21.6 (*t*); 21.1 (*t*); 17.9 (*q*); 17.5 (2*q*); 17.4 (*q*); 17.1 (*q*). FAB-MS: 521.3948 ([M + Na]$^+$), $C_{33}H_{54}NaO_3^+$; calc. 521.3971). Anal. calc. for $C_{33}H_{53}O_3$: C 79.5, H 11.0; found: C 79.5, H 11.0.

*(*E,E,E,E,E,E,E*)-5,9,13,17,21,25,29-Heptamethyl-31-[(tetrahydro-2*H*-pyran-2-yl)oxy]hentriaconta-5,9,13,17,21,25,29-heptaenal* (**17c**). DIBAL-H (55 µl, 82.50 µmol, 1.5M in toluene) and **16c** (45 mg, 71.20 µmol) were reacted according to the general procedure to give **17c** (40.5 mg, 89%). Colorless oil. IR ($CHCl_3$): 2926, 2853, 1721, 1666, 1451, 1384, 1116, 1075, 1034, 1021. ^{1}H-NMR (360 MHz, $CDCl_3$): 9.76 (*t*, *J* = 1.7, CHO); 5.37 (*dd*, *J* = 6.4, 7.4, C=C*H*CH$_2$O); 5.11 (*t*, *J* = 6.5, 6 C=CH); 4.63 (*t*, *J* = 3.5, OCHO); 4.24 (*dd*, *J* = 6.4, 11.8, 1 H, C=CHC*H*$_2$O); 4.03 (*dd*, *J* = 7.4, 11.8, 1 H, C=CHC*H*$_2$O); 3.93–3.87 (*m*, 1 H); 3.52–3.48 (*m*, 1 H); 2.39 (*dt*, *J* = 1.7, 7.3, C*H*$_2$CHO); 2.11–1.96 (*m*, 26 H); 1.88–1.81 (*m*, 2 H); 1.78–1.66 (*m*, 2 H); 1.68 (*s*, Me); 1.65–1.45 (*m*, 4 H); 1.60 (*s*, 6 Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 202.7 (*d*); 140.2 (*s*); 135.2 (*s*); 134.92 (*s*); 134.88 (2*s*); 134.7 (*s*); 133.6 (*s*); 125.6 (*d*); 124.4 (*d*); 124.21 (2*d*); 124.16 (*d*); 123.8 (*d*); 120.5 (*d*); 97.7 (*d*); 63.6 (*t*); 62.2 (*t*); 43.1 (*t*); 39.7 (4*t*); 39.6 (2*t*); 38.8 (*t*); 30.7 (*t*); 26.7 (4*t*); 26.6 (*t*); 26.3 (*t*); 25.5 (*t*); 20.2 (*t*); 19.6 (*t*); 16.4 (*q*); 16.0 (5*q*); 15.7 (*q*). EI-MS: 532.4645 ([$M - C_5H_{10}O_2$ (THP-OH)]$^+$, $C_{38}H_{60}O^+$; calc. 532.4644).

10. *Aldehyde Oxidation Leading to* **18**. *General Representative Procedure: (*E,E,E*)-5,9,13-Trimethyl-15-[(tetrahydro-2*H*-pyran-2-yl)oxy]pentadeca-5,9,13-trienoic Acid* (**18a**). A soln. of $NaClO_2$ (750 mg, 6.64 mmol, 80%) and KH_2PO_4 (750 mg, 5.51 mmol) in H_2O (5 ml) was added dropwise over 10 min to a stirred soln. of **17a** (273 mg, 0.753 mmol) in *t*-BuOH (15 ml) and 2-methylbut-2-ene (3 ml). The mixture was stirred vigorously for 1 h, diluted with H_2O and extracted with AcOEt. The combined org. extracts were washed with brine, dried ($MgSO_4$) and then evaporated *in vacuo* to leave **18a** (287 mg, 99%). Colorless oil. IR (film): 3650–2900, 2938, 1708, 1663, 1443, 1383, 1260, 1200, 1183, 1137, 1117, 1076, 1052, 1022. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.36 (*dd*, *J* = 6.4, 7.4, C=C*H*CH$_2$O); 5.12–5.09 (*m*, 2 C=CH); 4.64 (*t*, *J* = 3.5, OCHO); 4.24 (*dd*, *J* = 6.4, 11.9, 1 H, C=CHC*H*$_2$O); 4.04 (*dd*, *J* = 7.4, 11.9, 1 H, C=CHC*H*$_2$O); 3.93–3.87 (*m*, 1 H); 3.55–3.51 (*m*, 1 H); 2.30 (*t*, *J* = 7.5, C*H*$_2$CO$_2$H); 2.17–1.93 (*m*, 10 H); 1.88–1.83 (*m*, 1 H); 1.80–1.70 (*m*, 3 H); 1.68 (*s*, Me); 1.59 (*s*, 2 Me); 1.56–1.52 (*m*, 4 H). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 179.2 (*s*); 140.3 (*s*); 135.0 (*s*); 133.6 (*s*); 125.3 (*d*); 124.0 (*d*); 120.4 (*d*); 97.7 (*d*); 63.6 (*t*); 62.2 (*t*); 39.6 (*t*); 39.5 (*t*); 38.8 (*t*); 33.2 (*t*); 30.6 (*t*); 26.5 (*t*); 26.2 (*t*); 25.4 (*t*); 22.7 (*t*); 19.5 (*t*); 16.3 (*q*); 15.9 (*q*); 15.7 (*q*). EI-MS: 276.2078 ([$M - C_5H_{10}O_2$ (THP-OH)]$^+$, $C_{18}H_{28}O_2^+$; calc. 276.2089).

*(*E,E,E,E,E*)-5,9,13,17,21-Pentamethyl-23-[(tetrahydro-2*H*-pyran-2-yl)oxy]tricosa-5,9,13,17,21-pentaenoic Acid* (**18b**). $NaClO_2$ (113 mg, 1.25 mmol), KH_2PO_4 (113 mg, 0.83 mmol) and **17b** (78 mg, 0.16 mmol) were reacted according to the general procedure to give **18b** (75 mg, 93%). Colorless oil. IR (film): 3410, 2924, 1709, 1441, 1384, 1200, 1116, 1076, 1023. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.36 (*dd*, *J* = 6.4, 7.5, C=C*H*CH$_2$O); 5.11–5.08 (*m*, 4 C=CH); 4.65 (*t*, *J* = 3.4, OCHO); 4.25 (*dd*, *J* = 6.4, 11.9, 1 H, C=CHC*H*$_2$O); 4.05 (*dd*, *J* = 7.5, 11.9, 1 H, C=CHC*H*$_2$); 3.91–3.87 (*m*, 1 H); 3.53–3.49 (*m*, 1 H); 2.31 (*t*, *J* = 7.5, C*H*$_2$CO$_2$H); 2.15–1.95 (*m*, 18 H); 1.96–1.73 (*m*, 4 H); 1.68 (*s*, Me); 1.6 (*s*, 4 Me); 1.54–1.50 (*m*, 4 H). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 179.5 (*s*); 140.3 (*s*); 135.2 (*s*); 134.9 (*s*); 134.7 (*s*); 133.6 (*s*); 125.4 (*d*); 124.3 (*d*); 124.1 (*d*); 123.8 (*d*); 120.4 (*d*); 97.7 (*d*); 63.6 (*t*); 62.2 (*t*); 39.6 (2*t*); 39.6 (2*t*); 38.7 (*t*); 33.2 (*t*); 30.6 (*t*); 26.6 (2*t*); 26.5 (*t*); 26.2 (*t*); 25.4 (*t*); 22.7 (*t*); 19.5 (*t*); 16.4 (*q*); 15.9 (2*q*); 15.9 (*q*); 15.6 (*q*). FAB-MS: 537.1027 ([M + Na]$^+$; $C_{33}H_{54}NaO_4^+$; calc. 537.3920). Anal. calc. for $C_{33}H_{54}O_4$: C 77.0, H 10.6; found: C 77.3, H 10.8.

*(*E,E,E,E,E,E,E*)-5,9,13,17,21,25,29-Heptamethyl-31-[(tetrahydro-2*H*-pyran-2-yl)oxy]hentriaconta-5,9,13,17,21,25,29-heptaenoic Acid* (**18c**). $NaClO_2$ (50 mg, 0.443 mmol, 80%), KH_2PO_4 (50 mg, 0.367 mmol) and **17c** (36 mg, 56.69 µmol) were reacted according to the general procedure to give **18c** (35.2 mg, 95%). Colorless oil. IR ($CHCl_3$): 3600–3100, 2931, 1703, 1660, 1439, 1382, 1179, 1069. ^{1}H-NMR (360 MHz, $CDCl_3$): 5.36 (*dd*, *J* = 6.5, 7.5, C=C*H*CH$_2$O); 5.12–5.10 (*m*, 6 C=CH); 4.64 (*t*, *J* = 3.5, OCHO); 4.24 (*dd*, *J* = 6.5, 11.9, 1 H,

C=CHCH_2O); 4.03 (*dd*, *J* = 7.5, 11.9, 1 H, C=CHCH_2O); 3.92–3.87 (*m*, 1 H); 3.53–3.50 (*m*, 1 H); 2.30 (*t*, *J* = 7.6, CH_2CO$_2$H); 2.10–1.98 (*m*, 26 H); 1.85–1.83 (*m*, 2 H); 1.75–1.71 (*m*, 2 H); 1.68 (*s*, Me); 1.60–1.54 (*m*, 4 H); 1.60 (*s*, 6 Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 178.8 (*s*); 140.3 (*s*); 135.2 (*s*); 134.89 (*s*); 134.85 (2*s*); 134.7 (*s*); 133.6 (*s*); 125.4 (*d*); 124.3 (*d*); 124.2 (2*d*); 124.1 (*d*); 123.8 (*d*); 120.5 (*d*); 97.7 (*d*); 63.6 (*t*); 62.2 (*t*); 39.7 (5*t*); 39.6 (3*t*); 38.8 (*t*); 30.6 (*t*); 29.6 (*t*); 26.6 (3*t*); 26.3 (*t*); 25.4 (*t*); 22.7 (*t*); 19.5 (*t*); 16.4 (*q*); 16.0 (5*q*); 15.7 (*q*).

11. *Formation of* Se-*Phenyl Selenoate* **19**. *General Representative Procedure:* Se-*Phenyl (*E,E,E*)-5,9,13-Trimethyl-15-[(tetrahydro-2*H*-pyran-2-yl)oxy]pentadeca-5,9,13-trieneselenoate* (**19a**). Bu_3P (137 µl, 110 mg, 0.546 mmol) was added dropwise over 2 min to a stirred soln. of **18a** (140 mg, 0.370 mmol) in CH_2Cl_2 (2 ml) at −30°. After 2 min *N*-(phenylseleno)phthalimide (166 mg, 0.549 mmol) was added in a single portion, and the mixture was then stirred at −30° for 30 min. The mixture was diluted with H_2O and extracted with CH_2Cl_2. The combined org. extracts were washed with brine, dried ($MgSO_4$) and then evaporated *in vacuo*. FC (Et_2O/petrol 1:99 → 1:3) gave **19a** (136 mg, 71%). Colorless oil. IR (film): 3057, 2935, 1723, 1668, 1580, 1477, 1438, 1388, 1200, 1116, 1053, 1022. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.53–7.49 (*m*, 2 H); 7.41–7.36 (*m*, 3 H); 5.40–5.36 (*dd*, *J* = 6.4, 7.4, C=C*H*CH$_2$O); 5.13 (*t*, *J* = 6.7, 2 C=CH); 4.64 (*t*, *J* = 3.5, OCHO); 4.25 (*dd*, *J* = 6.4, 11.9, 1 H, C=CHCH_2O); 4.04 (*dd*, *J* = 7.4, 11.9, 1 H, C=CHCH_2O); 3.93–3.87 (*m*, 1 H); 3.55–3.49 (*m*, 1 H); 2.66 (*t*, *J* = 7.5, CH$_2$COSe); 2.16–1.98 (*m*, 10 H); 1.88–1.76 (*m*, 3 H); 1.75–1.71 (*m*, 1 H); 1.69 (*s*, Me); 1.66–1.53 (*m*, 4 H); 1.61 (*s*, Me); 1.59 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 200.3 (*s*); 140.2 (*s*); 135.7 (2*d*); 135.0 (*s*); 133.4 (*s*); 129.3 (2*d*); 128.8 (*d*); 126.5 (*s*); 125.7 (*d*); 124.0 (*d*); 120.6 (*d*); 97.8 (*d*); 63.6 (*t*); 62.2 (*t*); 46.8 (*t*); 39.61 (*t*); 39.57 (*t*); 38.5 (*t*); 30.7 (*t*); 26.5 (*t*); 26.3 (*t*); 25.5 (*t*); 23.4 (*t*); 19.6 (*t*); 16.4 (*q*); 16.0 (*q*); 15.6 (*q*). EI-MS: 416.1619 ([*M* − $C_5H_{10}O_2$ (THP-OH)]$^+$, $C_{24}H_{32}O^{80}Se^+$; calc. 416.1618).

Se-*Phenyl (*E,E,E,E,E*)-5,9,13,17,21-Pentamethyl-23-[(tetrahydro-2*H*-pyran-2-yl)oxy]tricosa-5,9,13,17,21-pentaeneselenoate* (**19b**). Bu_3P (14.4 µl, 11.8 mg, 58.40 mmol), **18b** (20 mg, 38.86 µmol) and *N*-(phenylseleno)phthalimide (17.6 mg, 58.43 µmol) were reacted according to the general procedure to give **19b** (14 mg, 55%). Colourless oil. IR (film): 2922, 1726, 1667, 1580, 1477, 1439, 1383, 1260, 1200, 1182, 1116,1076, 1053, 1022. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.5 (*m*, 2 H); 7.38 (*m*, 3 H); 5.38 (*dd*, *J* = 6.4, 7.4, C=C*H*CH$_2$O); 5.15–5.10 (*m*, 4 C=CH); 4.62 (*t*, *J* = 3.4, OCHO); 4.23 (*dd*, *J* = 6.4, 11.8, 1 H, C=CHCH_2O); 4.03 (*dd*, *J* = 7.4, 11.8, 1 H, C=CHCH_2O); 3.93–3.89 (*m*, 1 H); 3.55–3.49 (*m*, 1 H); 2.67–2.65 (*m*, CH$_2$COSe); 2.17–1.92 (*m*, 18 H); 1.92–1.70 (*m*, 4 H); 1.68 (*s*, Me); 1.61–1.59 (*s*, 4 Me); 1.58–1.52 (*m*, 4 H). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 200.3 (*s*); 140.2 (*s*); 135.7 (2*d*); 135.2 (*s*); 134.9 (*s*); 134.7 (*s*); 133.3 (*s*); 129.2 (2*d*); 128.7 (*d*); 126.5 (*s*); 125.7 (*d*); 124.3 (*d*); 124.1 (*d*); 123.8 (*d*); 120.5 (*d*); 97.7 (*d*); 63.6 (*t*); 62.2 (*t*); 46.7 (*t*); 39.7 (2*t*); 39.6 (*t*); 39.6 (*t*); 38.5 (*t*); 30.7 (*t*); 26.6 (2*t*); 26.5 (*t*); 26.3 (*t*); 25.4 (*t*); 23.3 (*t*); 19.6 (*t*); 16.4 (*q*); 16.0 (2*q*); 15.9 (*q*); 15.6 (*q*). FAB-MS: 677.3451 ([*M* + Na]$^+$, $C_{39}H_{58}NaO_3{}^{80}Se^+$; calc. 677.3449). Anal. calc. for $C_{39}H_{58}O_3Se$: C 71.5, H 8.9; found: C 71.5, H 9.2.

Se-*Phenyl (*E,E,E,E,E,E,E*)-5,9,13,17,21,25,29-Heptamethyl-31-[(tetrahydro-2*H*-pyran-2-yl)oxy]hentriaconta-5,9,13,17,21,25,29-heptaeneselenoate* (**19c**). Bu_3P (17 µl, 13.8 mg, 68.23 µmol), **18c** (30 mg, 46.08 µmol) and *N*-(phenylseleno)phthalimide (21 mg, 69.49 µmol) were reacted according to the general procedure to give **19c** (23.4 mg, 65%). Colorless oil. IR ($CHCl_3$): 3010, 2927, 1713, 1666, 1440, 1384, 1115, 1074, 1022. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.53–7.50 (*m*, 2 H); 7.39–7.36 (*m*, 3 H); 5.38 (*dd*, *J* = 6.5, 7.5, C=C*H*CH$_2$O); 5.14–5.10 (*m*, 6 C=CH); 4.64 (*t*, *J* = 3.4, OCHO); 4.25 (*dd*, *J* = 6.5, 11.9, 1 H, C=CHCH_2O); 4.04 (*dd*, *J* = 7.5, 11.9, 1 H, C=CHCH_2O); 3.94–3.88 (*m*, 1 H); 3.55–3.49 (*m*, 1 H); 2.67 (*t*, *J* = 7.4, CH$_2$COSe); 2.10–2.00 (*m*, 26 H); 1.80 (app. *quint.*, *J* = 7.4, CH_2CH$_2$COSe); 1.78–1.73 (*m*, 2 H); 1.72–1.66 (*m*, 2 H); 1.69 (*s*, Me); 1.61 (*s*, 4 Me); 1.59 (*s*, Me); 1.58 (*s*, Me); 1.57–1.51 (*m*, 2 H). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 200.3 (*s*); 140.3 (*s*); 135.8 (2*d*); 135.3 (*s*); 135.0 (*s*); 134.9 (2*s*); 134.7 (*s*); 133.4 (*s*); 129.3 (2*d*); 128.8 (*d*); 126.5 (*s*); 125.8 (*d*); 124.4 (*d*); 124.22 (2*d*); 124.17 (*d*); 123.9 (*d*); 120.5 (*d*); 97.8 (*d*); 63.6 (*t*); 62.3 (*t*); 46.8 (*t*); 39.7 (4*t*); 39.6 (2*t*); 38.5 (*t*); 30.7 (*t*); 26.7 (4*t*); 26.6 (*t*); 26.3 (*t*); 25.5 (*t*); 23.4 (*t*); 19.6 (*t*); 16.4 (*q*); 16.0 (5*q*); 15.7 (*q*).

12. *Acetal Deprotection Leading to* **5**. *General Representative Procedure:* Se-*Phenyl (*E,E,E*)-15-Hydroxy-5,9,13-trimethylpentadeca-5,9,13-trieneselenoate* (**5a**). A soln. of TsOH · H_2O (9 mg, 0.048 mmol) in MeOH (5 ml) was added dropwise to **19a** (120 mg, 0.232 mmol), and the mixture was stirred at r.t. for 4 h. The mixture was diluted with a 5% aq. soln. of $NaHCO_3$ and extracted with Et_2O. The combined org. extracts were washed with brine, dried ($MgSO_4$) and then evaporated *in vacuo*. FC (Et_2O/petrol 1:4 → 1:1) gave **5a** (92 mg, 92%). Colorless oil. IR ($CHCl_3$): 2927, 2854, 1717, 1668, 1580, 1478, 1440, 1384, 1158, 1102, 1065. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.52–7.49 (*m*, 2 H); 7.40–7.36 (*m*, 3 H); 5.45 (*t*, *J* = 6.8, C=C*H*CH$_2$OH); 5.13 (*t*, *J* = 6.8, 2 C=CH); 4.15 (*d*, *J* = 6.8, CH$_2$O); 2.67 (*t*, *J* = 7.5, CH$_2$COSe); 2.18–1.98 (*m*, 10 H); 1.80 (app. *quint.* *J* = 7.5, CH_2CH$_2$COSe); 1.69 (*s*, Me); 1.61 (*s*, Me); 1.59 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 200.3 (*s*); 140.2 (*s*); 135.7 (2*d*); 135.1 (*s*); 133.5 (*s*); 129.3 (2*d*); 128.8 (*d*); 126.5 (*s*); 125.6 (*d*); 123.9 (*d*); 123.4 (*d*); 59.4 (*t*); 46.8 (*t*); 39.6 (*t*); 39.5 (*t*); 38.5 (*t*); 26.5 (*t*); 26.3 (*t*); 23.4 (*t*); 16.3 (*q*); 16.0 (*q*); 15.7 (*q*). 277.2175 ([*M* − C_6H_5Se]$^+$, $C_{18}H_{29}O_2^+$; calc. 277.2168).

Se-*Phenyl* (E,E,E,E,E)*-23-Hydroxy-5,9,13,17,21-pentamethyltricosa-5,9,13,17,21-pentaeneselenoate* (**5b**). $TsOH \cdot H_2O$ (1.5 mg, 7.89 μmol), MeOH (1 ml) and **19b** (25 mg, 38 μmol) were reacted according to the general procedure to give **5b** (18 mg, 83%). Colorless oil. IR (film): 3355, 2920, 1725, 1439. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.50 (*m*, 2 H); 7.34 (*m*, 3 H); 5.44–5.42 (*m*, C=C*H*CH_2OH); 5.14–5.10 (*m*, 4 C=CH); 4.15 (*d*, *J* = 6.9, CH_2O); 2.65 (*t*, *J* = 7.4, CH_2COSe); 2.18–1.95 (*m*, 18 H); 1.82–1.79 (*m*, 2 H); 1.69 (*s*, Me); 1.61 (*s*, 3 Me); 1.59 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 200.3 (*s*); 139.7 (*s*); 135.7 (2*d*); 135.3 (*s*); 134.9 (*s*); 134.7 (*s*); 133.4 (*s*); 129.2 (2*d*); 128.7 (*d*); 126.5 (*s*); 125.7 (*d*); 124.3 (*d*); 124.1 (*d*); 123.7 (*d*); 123.2 (*d*); 59.3 (*t*); 46.8 (*t*); 39.7 (*t*); 39.6 (*t*); 39.5 (*t*); 38.5 (*t*); 26.6 (3*t*); 26.5 (*t*); 26.3 (*t*); 16.2 (*q*); 16.0 (2*q*); 15.9 (*q*); 15.6 (*q*). FAB-MS: 570.3185 (M^+, $C_{34}H_{50}O_2{}^{80}Se^+$; calc. 570.2976).

Se-*Phenyl* (E,E,E,E,E,E,E)*-31-Hydroxy-5,9,13,17,21,25,29-heptamethylhentriaconta-5,9,13,17,21,25,29-heptaeneselenoate* (**5c**). $TsOH \cdot H_2O$ (1.0 mg, 5.26 μmol), MeOH (1 ml) and **19c** (22 mg, 27.84 μmol) were reacted according to the general procedure to give **5c** (18.6 mg, 94%). Colorless oil. IR ($CHCl_3$): 3650, 2929, 2851, 1667, 1575, 1474, 1438, 1381, 1104, 1066. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.52–7.49 (*m*, 2 H); 7.40–7.35 (*m*, 3 H); 5.43 (*dt*, *J* = 1.2, 6.8, C=C*H*CH_2OH); 5.14–5.10 (*m*, 6 C=CH); 4.16 (*d*, *J* = 6.8, CH_2O); 2.67 (*t*, *J* = 7.5, CH_2COSe); 2.16–1.99 (*m*, 26 H); 1.82 (app. *quint.* *J* = 7.5, CH_2CH_2COSe); 1.69 (*s*, Me); 1.61 (*s*, 5 Me); 1.59 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 200.4 (*s*); 139.8 (*s*); 135.8 (2*d*); 135.4 (*s*); 135.0 (*s*); 134.93 (*s*); 134.91 (*s*); 134.7 (*s*); 133.4 (*s*); 129.3 (2*d*); 128.8 (*d*); 126.5 (*s*); 125.8 (*d*); 124.4 (*d*); 124.24 (*d*); 124.21 (*d*); 124.1 (*d*); 123.7 (*d*); 123.3 (*d*); 59.4 (*t*); 46.8 (*t*); 39.7 (4*t*); 39.6 (*t*); 39.5 (*t*); 38.5 (*t*); 26.7 (3*t*); 26.64 (*t*); 26.59 (*t*); 26.3 (*t*); 23.4 (*t*); 16.3 (*q*); 16.0 (5*q*); 15.6 (*q*).

13. *Radical-Mediated Reductive Cyclisations of* Se-*Phenyl Selenoates* **5**. *General Representative Procedure: Reductive Cyclisation of* **5a**. A soln. of Bu_3SnH (63 μl, 68 mg, 0.233 mmol) and AIBN (10 mg) in benzene (5 ml) was added dropwise over 8 h to a refluxing soln. of **5a** (84 mg, 0.194 mmol) and AIBN (5 mg) in dry degassed benzene (60 ml). The mixture was heated under reflux for a further 6 h, then cooled and the solvent removed *in vacuo*. FC (Et_2O/petrol 1:4 → 4:1) gave **20** (28 mg, 52%). White crystalline solid. M.p. 95–97° (from AcOEt/pentane). IR ($CHCl_3$): 3690, 3624, 3007, 2940, 2877, 2854, 1701, 1450, 1387, 1345, 1309, 1285, 1185, 1159, 1107, 1064, 1014. ^{1}H-NMR (500 MHz, $CDCl_3$): 3.86 (*dd*, *J* = 4.7, 10.3, 1 H, C*H*$_2$); 3.60 (app. *t*, *J* = 10.3, 1 H, C*H*$_2$OH); 2.32–2.22 (*m*, 2 H); 2.17 (*dd*, *J* = 4.4, 10.5); 2.00–1.96 (*m*, *ca.* 2 H); 1.93–1.76 (*m*, *ca.* 3 H); 1.73–1.70 (*m*, *ca.* 2 H); 1.63–1.49 (*m*, *ca.* 4 H); 1.49–1.33 (*m*, *ca.* 3 H); 0.95 (*d*, *J* = 7.6, *Me*CH); 0.88 (*s*, Me); 0.72 (*s*, Me). ^{13}C-NMR (125.8 MHz, $CDCl_3$): 213.5 (*s*); 60.7 (*t*); 59.5 (*d*); 58.8 (*d*); 55.8 (*d*); 43.2 (*s*); 40.7 (*t*); 38.7 (*t*); 38.2 (*t*); 37.5 (*s*); 34.3 (*t*); 28.3 (*d*); 22.1 (*t*); 17.9 (*q*); 17.3 (*t*); 16.8 (*t*); 15.5 (*q*); 14.0 (*q*). EI-MS: 278.2242 (M^+, $C_{18}H_{30}O_2^+$; calc. 278.2246).

Reductive Cyclisation of **5b**. Bu_3SnH (22 μl, 24 mg, 82.5 μmol), AIBN (6 mg) and **5b** (38 mg, 66.7 μmol) were reacted to give, after FC (Et_2O/petrol 1:1), **23** (14 mg, 51%). White crystalline solid. M.p. 260–262° (from AcOEt/CH_2Cl_2). IR ($CHCl_3$): 2920, 1702, 1038. ^{1}H-NMR (360 MHz, $CDCl_3$): 3.85 (*dd*, *J* = 4.8, 10.6, 1 H, C*H*$_2$OH); 3.60 (app. *t*, *J* = 10.6, 1 H, C*H*$_2$OH); 2.35–1.02 (complex series of *m*s); 0.95 (*d*, *J* = 7.5, *Me*CH); 0.86 (*s*, 2 Me); 0.84 (*s*, Me); 0.72 (*s*, Me). ^{13}C-NMR (90.6 MHz, $CDCl_3$): 213.9 (*s*); 61.6 (*d*); 61.3 (*d*); 61.0 (*t*); 59.7 (*d*); 59.0 (*d*); 56.2 (*d*); 43.5 (*s*); 42.0 (*t*); 41.9 (*t*); 40.9 (*t*); 38.8 (*s*); 38.2 (*t*); 37.9 (*s*); 37.8 (*s*); 37.5 (*t*); 34.6 (*t*); 28.4 (*d*); 22.4 (*t*); 18.2 (2*q*); 17.7 (*q*); 17.1 (2*t*); 16.9 (*t*); 16.4 (*t*); 15.5 (*q*); 13.9 (*q*). FAB-MS: 437.3567 ($[M + Na]^+$, $C_{28}H_{46}O_2^+$; calc. 437.3398).

Reductive Cyclisation of **5c**. Bu_3SnH (8 μl, 8.7 mg, 29.8 μmol), AIBN (1.5 mg) and **5c** (16.8 mg, 23.9 μmol) were reacted to give, after FC (Et_2O/petrol 3:7 → 4:1): **25** (2.3 mg, 17%) and **27** (3.7 mg, 28%).

Data of **25**. White crystalline solid. M.p. 269–271° (dec.) (from AcOEt/pentane). IR ($CHCl_3$): 2920, 3626, 2928, 2853, 1700, 1465, 1387, 1260, 1110, 1010. ^{1}H-NMR (500 MHz, $CDCl_3$): 3.85 (*dd*, *J* = 4.3, 10.4, 1 H, C*H*$_2$OH); 3.59 (app. *t*, *J* = 10.4, 1 H, C*H*$_2$OH); 2.31–2.27 (*m*, 2 H); 2.14–0.74 (complex series of *m*s); 0.95 (*d*, *J* = 7.6, *Me*CH); 0.85 (*s*, Me); 0.84 (*s*, Me); 0.81 (*s*, 2 Me); 0.79 (*s*, Me); 0.71 (*s*, Me). ^{13}C-NMR (125.8 MHz, $CDCl_3$): 213.8 (*s*); 61.6 (*d*); 61.5 (*d*); 61.4 (2*d*); 60.9 (*t*); 59.7 (*d*); 59.1 (*d*); 56.1 (*d*); 43.4 (*s*); 42.0 (*t*); 41.9 (*t*); 41.8 (*t*); 41.7 (*t*); 40.8 (*t*); 38.7 (*t*); 38.1 (*t*); 37.8 (2*s*); 37.7 (*s*); 37.6 (*s*); 37.5 (*s*); 34.5 (*t*); 28.3 (*d*); 22.3 (*t*); 18.2 (*t*); 18.2 (*q*); 17.4 (*q*); 17.3 (*q*); 17.2 (*q*); 17.11 (*t*); 17.07 (2*t*); 17.0 (*q*); 16.9 (*t*); 16.2 (*t*); 15.4 (*q*); 13.8 (*q*). CI-MS: 533.4704 ($[M + H - H_2O]^+$, $C_{38}H_{61}O^+$; calc. 533.4722).

Data of **27**. Colorless oil. IR ($CHCl_3$): 2938, 2875, 2852, 1698, 1663, 1451, 1386, 1265, 1228. ^{1}H-NMR (500 MHz, $CDCl_3$): 5.43 (*t*, *J* = 6.7, C=C*H*CH_2OH); 5.13–5.10 (*m*, 2 C=CH); 4.16 (*d*, *J* = 6.7, C*H*$_2$OH); 2.27–0.80 (complex series of *m*s); 1.68 (*s*, MeC=C); 1.60 (*s*, 2 MeC=C); 0.91 (*d*, *J* = 7.1, *Me*CH); 0.86 (*s*, Me); 0.85 (*s*, Me); 0.84 (*s*, Me). ^{13}C-NMR (125.8 MHz, $CDCl_3$): 213.8 (*s*); 139.8 (*s*); 135.4 (*s*); 135.0 (*s*); 124.2 (*d*); 123.7 (*d*); 123.3 (*d*); 65.8 (*t*); 61.4 (*d*); 61.1 (*d*); 59.7 (*d*); 51.9 (*d*); 43.4 (*s*); 42.0 (*t*); 41.8 (*t*); 40.8 (*t*); 39.7 (*t*); 39.5 (*t*); 38.1 (*t*); 38.0 (*t*); 37.7 (*t*); 37.5 (*s*); 37.4 (*s*); 30.3 (*d*); 26.6 (*t*); 26.3 (*t*); 22.3 (*t*); 21.4 (*t*); 17.3 (2*q*); 17.1 (3*t*); 16.3 (*q*); 16.0 (*q*); 15.9 (*q*); 15.3 (*q*); 13.8 (*q*). EI-MS: 532.4669 ($[M - H_2O]^+$, $C_{38}H_{60}O^+$; calc. 532.4644).

REFERENCES

[1] G. Stork, A. W. Burgstahler, *J. Am. Chem. Soc*. **1955**, *77*, 5068; A. Eschenmoser, L. Ruzika, O. Jeger, D. Arigoni, *Helv. Chim. Acta* **1955**, *38*, 1890.

[2] J. K. Sutherland, 'Polyene Cyclisations' in Comprehensive Organic Synthesis, Ed. B. M. Trost, Pergamon, Oxford, UK, 1991, Vol. 3, p. 341; W. S. Johnson, W. R. Bartlett, B. A. Czeskis, A. Gautier, C. H. Lee, R. Lemoine, E. J. Leopold, G. R. Luedtke, K. J. Bancroft, *J. Org. Chem*. **1999**, *64*, 9587; P. V. Fish, W. S. Johnson, G. S. Jones, F. S. Tham, R. K. Kullnig, *J. Org. Chem*. **1994**, *59*, 6150; E. J. Corey, J. Lee, *J. Am. Chem. Soc*. **1993**, *115*, 8873.

[3] S. Tomida, T. Doi, T. Takahashi, *Tetrahedron Lett*. **1999**, *40*, 2363; P. A. Zoretic, H. Fang, A. A. Ribeiro, *J. Org. Chem*. **1998**, *63*, 7213; S. Wu, M. Journet, M. Malacria, *Tetrahedron Lett*. **1994**, *35*, 2363.

[4] a) S. A. Hitchcock, S. J. Houldsworth, G. Pattenden, D. C. Pryde, N. M. Thomson, A. J. Blake, *J. Chem. Soc., Perkin Trans. 1* **1998**, 3183; b) P. Jones, W. S. Li, G. Pattenden, N. M. Thomson, *Tetrahedron Lett*. **1997**, *38*, 9069; c) G. Pattenden, P. Wiedenau, *Tetrahedron Lett*. **1997**, *38*, 3647.

[5] A. Batsanov, L. G. Chen, G. B. Gill, G. Pattenden, *J. Chem. Soc., Perkin Trans. 1* **1996**, 45.

[6] S. Handa, G. Pattenden, W. S. Li, *Chem. Commun*. **1998**, 311.

[7] S. Handa, G. Pattenden, *J. Chem. Soc., Perkin Trans. 1* **1999**, 843.

[8] I. Jondiko, G. Pattenden, *Phytochemistry* **1989**, *28*, 3159.

[9] a) L. J. Altman, L. Ash, S. Marson, *Synthesis* **1974**, 129; b) Y. Masaki, K. Hashimoto, H. Iwai, K. Kaji, *Chem. Lett*. **1978**, 1203.

[10] K. Sato, S. Inoue, A. Onishi, N. Uchida, N. Minowa, *J. Chem. Soc., Perkin Trans. 1* **1981**, 761.

[11] E. E. van Tamelen, R. G. Nadeau, *Biorg. Chem*. **1982**, *11*, 197.

[12] N. J. G. Cox, S. D. Mills, G. Pattenden, *J. Chem. Soc., Perkin Trans. 1* **1992**, 1313.

[13] K. C. Nicolaou, N. A. Petasis, D. A. Claremon, *Tetrahedron* **1985**, *41*, 4835.

[14] D. S. de Miranda, G. Brendolan, P. M. Imamura, M. González Sierra, A. J. Marsaioli, E. A. Rúveda, *J. Org. Chem.* **1981**, *46*, 4851.

[15] H. Beierbeck, J. K. Saunders, J. W. Apsimon, *Can. J. Chem*. **1977**, *55*, 2813; H. Beierbeck, J. K. Saunders, *Can. J. Chem*. **1975**, *53*, 1307.

[16] P. A. Partlett in 'Asymmetric Synthesis', Ed. J. D. Morrison, Academic Press, New York, 1984, Vol. 3, p. 341.

[17] C. Chatgiliaglu, D. Crich, M. Komatsu, I. Ryu, 'Chemistry of Acyl Radicals', in *Chem. Rev*. **1999**, *99*, 1991.

Received June 5, 2000