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SYNTHESIS OF (6Z)-CIS-9S,10R-EPOXYHENEICOSENE, A COMPONENT OF THE RUBY TIGER MOTH PHEROMONE

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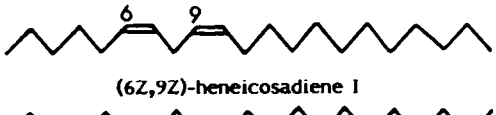
Abstract: A 10-step synthesis of the titled pheromone and analogues from an acyclic derivative of D-Xylose is described.

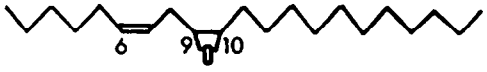
The sex pheromones of only a few species in the Arctiidae family have been reported to date. Recently, four compounds have been identified as components of the sex pheromone emitted by females of the ruby tiger moth[1], Phragmatobia fuliginosa (L). These are (6Z,9Z)-heneicosadiene **I**, (3Z,6Z,9Z)-heneicosatriene **II**, (6Z)-cis-9,10-epoxyheneicosene **III**, (3Z,6Z)-cis-9,10-epoxyheneicosadiene **IV**. In female abdominal tip extracts, compounds **III** and **IV** were found in a 15:85 ratio, respectively. The cis-epoxydiene **IV** has recently been identified as the major product of the sex pheromone system of Hyphantria cunea[2,3] as well as of Estigmene acrea[4]. Electroantennographic (E.A.G.) analyses with the two synthetic enantiomers[5] of **IV** showed that the 9S,10R isomer elicits a male antennal response two to three times greater than the 9R,10S isomer with Hyphantria cunea and with Estigmene acrea.

(6Z)-cis-9,10-Epoxyheneicosene **III** had never been described before as a component of sex pheromones in Lepidoptera. Based on the above assumptions, a 9S,10R configuration at the epoxy group of **III** was predicted and chiral synthesis of **III** and some of its analogues was undertaken.



(6Z,9Z)-heneicosadiene I

(3Z,6Z,9Z)-heneicosatriene II



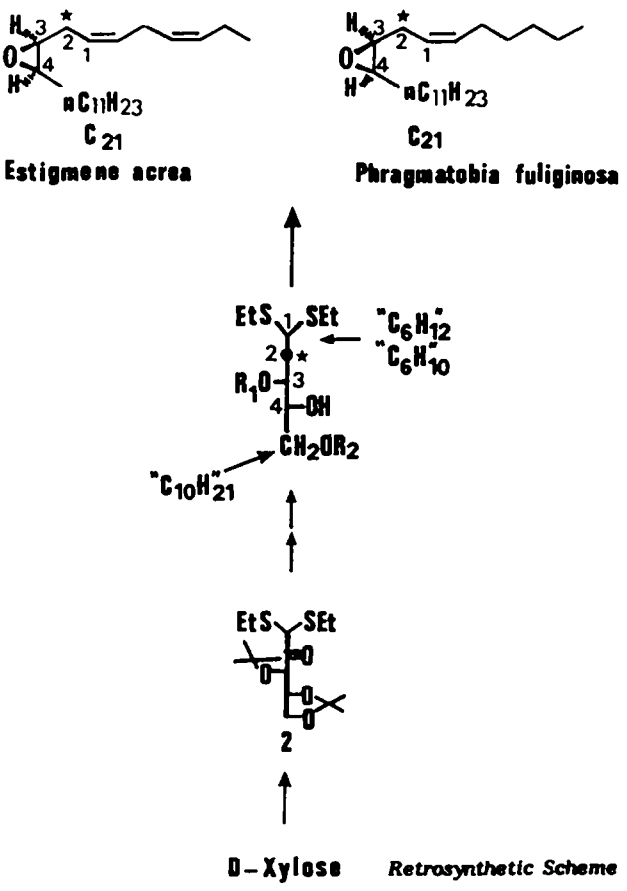
(6Z)-9,10-epoxyheneicosene III

(3Z,6Z)-cis-9,10-epoxyheneicosadiene IV

We have now synthesized compound **III** in pure optically active form starting from D-Xylose diethyl dithioacetal.

Carbohydrates are widely used for enantiomeric synthesis of optically active biological compounds[6]. Due to their preferred $^4C_1$ conformation, D-hexopyranosides offered a good deal of regio and stereochemical events. Until now, aliphatic derivatives have found very restricted use in total synthesis. Recently, L- and D-Arabinose diethyl dithioacetals were proved to be very useful starting materials for the synthesis of leucotriene B_4[7] and lipoxines[8]. For our purpose, we thought that D-Xylose diethyl dithioacetal could be of valuable interest.

The synthesis of pheromone III was planned according to the following retrosynthetic scheme.

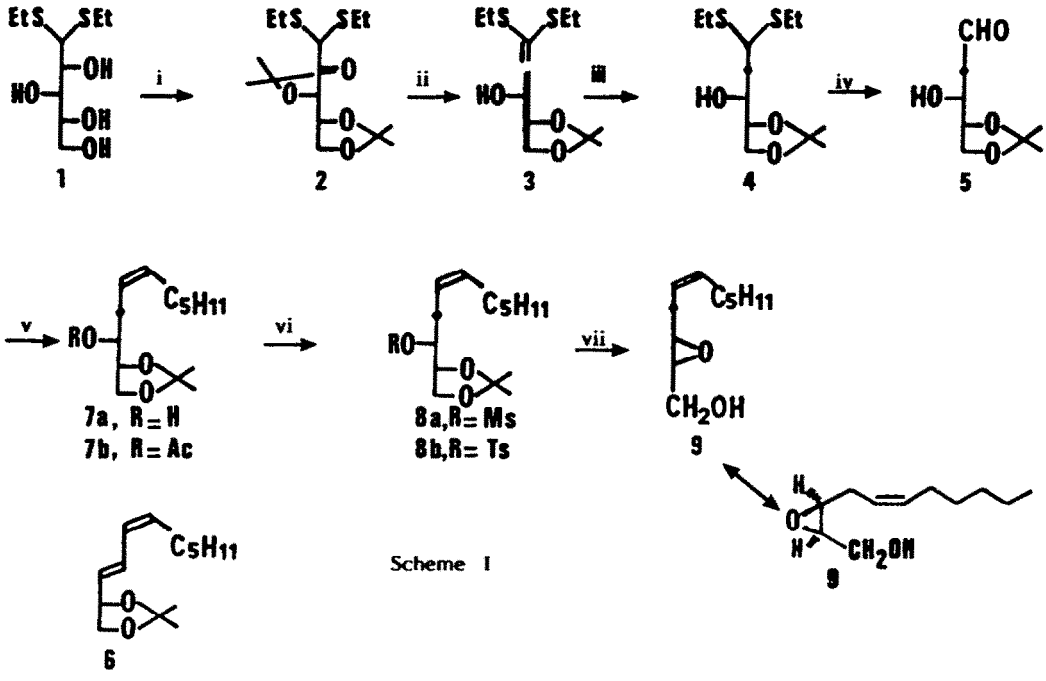


D-Xylose diethyl dithioacetal 1, a very common protected derivative of a monosaccharide, could be prepared and transformed into the 2,3-4,5-di-O-isopropylidene derivative 2 on a large scale. The diethyl dithioacetal function, a masked form of an aldehyde, allowed the deoxygenation at C2 at an early stage of the synthesis, using a very convenient methodology. Then, C3 and C4 asymmetric carbons of the starting material could be directly transferred to the C9-C10 oxiran ring of the pheromone III.

Introduction of the saturated aliphatic chain was planned using the nucleophilic displacement of a primary tosylate by cuprate reagents. In our particular case, it was of interest to investigate such a reaction towards and α-epoxy tosylate in order to define the limits of this methodology.

The ten-step synthesis of pheromone III was realized according to Scheme I.

Our first concern was the preparation of the epoxytosylate 10, a useful precursor for carbon-carbon bond formation. Large scale preparation of D-Xylose diethyl dithioacetal 1 was possible using a modified extractive work-up of the reactions previously described[9,10]. Neutralization of the very acidic reaction mixture with ammonium hydroxide solution provided a very convenient and low cost procedure. Compound 1, isolated as a pure cristalline material, was directly used for acetonation according to Ref. 11. The 2,3-4,5-di-O-isopropylidene-D-Xylose diethyl dithioacetal 2 was distilled prior to being used in the next step. Deoxygenation at the C2 position was then possible using a reaction developed by M.Y.H. Wong and G.R. Gray[12]. Under anhydrous conditions, treatment of compound 2 with potassium t-butoxide afforded the ketene dithioacetal 3 which was isolated in 86% yield. Reduction of 3 could be realized using either lithium alumini-



Scheme I

i,anhydrous $CuSO_4$, H_2SO_4, acetone; ii, t-BuOK,THF/DMSO, RT; iii, $LiAlH_4$, THF,RT or Red-Al, PhMe, 0°C;iv, Red HgO, BF_3-Et_2O, THF/H_2O, RT; v, $Ph_3P^+CH_2C_5H_{11}$, Br^-, $NaNH_2$, THF/HMPT, -78°C to RT; vi, MsCl, Pyr., RT or TsCl, Pyr., DMAP, RT; vii, TsOH-H_2O, MeOH, 0°C then MeONa, MeOH/CH_2Cl_2,0°C.

um hydride in ether[12] or Red-Al in toluene[13]. For large scale preparation of the 2-deoxy compound **4**, Red-Al proved to be a more convenient reagent than $LiAlH_4$, allowing a very clean transformation of **3**, an easier work-up of the reaction mixture and a better yield in compound **4**.

The 2-deoxy-4,5-O-isopropylidene-D-threo-pentose diethyl dithioacetal **4** was then submitted to the desulfurization step. Using the method developed by P.L. Fuchs[14], the aldehyde **5** was isolated in a quantitative yield. It was directly used for the Wittig reaction without further purification.

A hydroxyl group was compatible and did not impair the Wittig reaction[15,16]. In the β-position of the Wittig reagent, it favored the stereoselective formation of the trans allylic alcohol[17].

Oxaphospholanes (the cyclized form of γ-alkoxy phosphonium derivatives) have been reported to be stereoselective Wittig reagents[18]. When reacted with aldehydes, they give trans homoallylic alcohols, the mechanism of this selectivity being discussed in terms of an internal Schlosser "trans-selective Wittig" reaction[19]. With our substrates, the situation was reversed since reaction occurred between a non hydroxylated non stabilized ylide (n-hexylidene triphenylphosphorane) and the β-hydroxy aldehyde **5**. An extensive study of this reaction was undertaken. In every case, a homoallylic alcohol was isolated, homogeneous on t.l.c. 300 MHz ^{1}H-N.m.r. study did not allow us to ensure the purity of the Z-isomer. However, the $J_{5,6}$ value = 11.0 Hz was in agreement with the Z geometry. Careful examination of the ^{13}C-n.m.r. spectra and G.C-M.S analyses of the acetate **7b** allowed us to determine the Z:E ratio. Results are summarized in Table I and II. Experimental conditions which gave the best yield of Z-isomer **7a** were then selected for our purpose.

Table I

ylide formation	Compound **7b** Z:E ratio (GC-MS)	Elimination product **6** (%)	$[\alpha]_D^{20}$ (c, CCl_4) Compound **7b**	Compound **7a** (%)
THF-HMPT (9:1) $NaNH_2$ -78°C	90:10	6	-9° (2.02)	71
THF, n-BuLi -78°C	62:38	-	-8° (2.13)	65
THF-HMPT n-BuLi -100°C	61:39	15	-9° (1.14)	49

Z:E isomer ratio is largely dependent on solvent and cation effects. Note that specific rotation is unaffected by the geometry of the olefinic linkage in compound 7b.

Table II

	C_4	C_5	C_6	C_7
Z-isomer	28.9	133.5	123.5	27.3
E-isomer	34.3	134.6	124.2	32.6

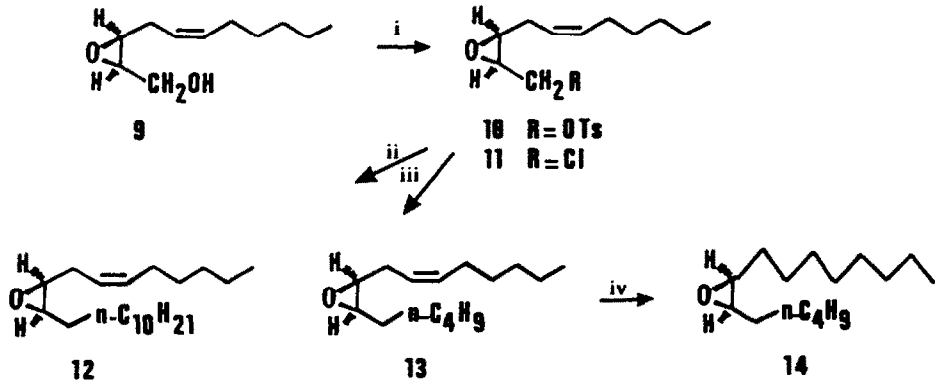
*^{13}C-N.m.r. chemical shifts (ppm) of homoallylic acetates **7b** (in $CDCl_3$). The differences in the α-carbon shieldings for the Z-E pair range from 4.7 to 6.8 ppm, with a mean difference of 6.0 ± 0.6 ppm (Ref. 20).*

In order to ensure oxirane ring formation, the homoallylic alcohol **7a** was mesylated. Tosylation could also be possible but this latter reaction needed DMAP as a catalyst and a longer time to undergo completion. The mesylated derivative **8a**, obtained in a 96% yield, was selected for the next step. Treatment of compound **8a** (or **8b**) with an excess of p-toluene sulfonic acid monohydrate (1.4 eq) in methanolic solution cleanly yielded the intermediate diol which was not isolated. The reaction mixture was then made alkaline with 1M MeONa in methanol. This one-pot transformation allowed the isolation of the epoxy alcohol **9** in 86% yield (77% after distillation).

In view of the known rearrangement of α,β-epoxy alcohols[21], a spectroscopic investigation was undertaken to confirm the proposed structure **9**. The occurrence of a methylene resonance at 60.9 ppm in the ^{13}C-n.m.r. spectrum permitted the ruling out of a primary epoxide. C_2 and C_3 of the epoxide **9** exhibited a single peak (δ:56.8 ppm). When the SFORD (Single Frequency Off-Resonance Decoupling) technique was applied, C_1 was observed as a triplet (δ:60.9 ppm; J_{CH} = 31.0 Hz) while C_2 and C_3 showed a doublet (δ:56.2 ppm; J_{CH} = 31.4 Hz). In the presence of the relaxation reagent $Cr(Acac)_3$, C_2 and C_3 signals appeared (δ:56.3 and 56.6 ppm). ^1H-N.m.r. (300 MHz) did confirm the structure. The first order spectrum showed H_2 (δ:3.16 ppm) and H_3 (δ:3.05 ppm) as two ddd [$J_{2,3}$ = 4.3 Hz]. Although linear correlation between that coupling constant and electronegativity of substituents could not be made[22], a value of 4.3 Hz would indicate a cis situation[23].

Finally, the key compound **10** was isolated after tosylation of the epoxy alcohol in 60% yield (25% overall yield from D-Xylose). Epoxy alcohol **9** exhibited a pseudo allylic character during this reaction since formation of the primary chloride **11** (8%) could not be avoided, even when working at low temperature. Such a behaviour was recently reported by K.C. Nicolaou[24a].

Our second concern was the introduction of a saturated aliphatic chain at C_1 position of the epoxy tosylate **10** (Scheme II).



9 **10** R=OTs **11** R=Cl **12** **13** **14**

i, TsCl, Pyr., 3°C; ii, $(n\text{-}C_{10}H_{21})_2CuLi$, Et_2O, -30°C or $(n\text{-}C_{10}H_{21})_2CuCNLi_2$, THF,-30°C to -10°C; iii, $(n\text{-}C_4H_9)_2CuLi$, Et_2O, -30°C or $(n\text{-}C_4H_9)_2CuCNLi_2$, THF, -30°C to -10°C; iv, H_2, PtO_2, PhMe.

Scheme II

The coupling reaction of a wide variety of lithium diorganocuprates with primary tosylates have been found to proceed in high yield[25] although it suffered from a few limitations in the case of polyoxygenated substrates[26,27]. However, the coupling reaction of lithium di-n-decylcuprate with an epoxy tosylate was recently reported[4b,5] to proceed in a 33 to 44% yield during the synthesis of the pheromone **IV**. This methodology gave rather poor yields in our particular case.

Earlier reports from B.H. Lipshutz[28] have demonstrated that the simple yet subtle shift from copper halide based organocuprates to copper cyanide derived species lead to a new class of highly reactive yet thermally stable reagents of general formula $R_2Cu(CN)Li_2$. Indeed, the best yields of coupling products were obtained when dilithium di-n-decylcyanocuprate or dilithium-di-n-butyl-cyanocuprate were used: compound **12** (pheromone **III**) was isolated in 44% yield and the analogue **13** was isolated in 52% yield. It has been proved that both acyclic bromides and iodides gave excellent yields of branched-chain products while mesylates were inert and only tosylates reacted to any extent (ca. 5-60%)[28]. It has also been demonstrated that cyanocuprates reacted with mono-, di- and trisubstituted epoxides [28]. Our substrate **10** is the first example where both epoxide and tosyl functionality were present in a structure. Actually, tosylate displacement occurred prior to epoxide opening, but this side reaction could not be totally avoided.

Pheromone **III** (compound **12**) has been fully characterized. The only report concerning **III** is a mass spectrum[1] (Nitrogen Oxide chemical ionization mode). Mass spectra of the natural product and the synthetic sample were both identical. Although the $J_{6,7}$ value (11.0 Hz) in the ^{1}H-n.m.r. spectrum was in agreement with the Z geometry of the double bond, the presence of 10% of the E-isomer could only be detected by G.C. analysis (25 m. WCOT, 0.22 id, CPSIL 5 CB column, 240°C, p.He = 0.5 b). An analytical sample of the E-isomer could be isolated. Its ^{1}H 300 MHz n.m.r. spectrum exhibited two signals corresponding to the olefinic protons at δ 5.56 ppm (H_6) and δ 5.42 ppm (H_7) with a coupling constant value $J_{6,7}$ = 15.5 Hz. The positive value ($[\alpha]_D^{20}$ = +5.5°) of the specific rotation of the synthetic pheromone **III** having the 9S,10R configuration at the oxirane ring corroborated the positive value ($[\alpha]_D^{23}$ = +3.4°) of the corresponding (3Z,6Z)-cis-9S,10R-epoxyheneicosadiene **IV** which was recently synthesized[4b].

The analogue **13** has been synthesized, which proved to be contaminated with 10% of E-**13** isomer (^{13}C-n.m.r. experiment). Hydrogenation of compound **13** over Adams catalyst produced the third analogue **14**.

Compounds **12**, **13** and **14** are now being tested at the Laboratoire des Médiateurs Chimiques (I.N.R.A., Brouessy) for their final purification (H.P.L.C.) and their biological activity. Results concerning the E.A.G. activity of these three compounds will be reported as soon as possible elsewhere. Conformational study of these molecules is currently under investigation. Compilation of these results could enable us to define a structure-activity relationship.

Starting from D-Xylose, we have synthesized the (6Z)-cis-9S,10R-epoxyheneicosene **III** (compound **12**), the minor component of the sex pheromone emitted by the females of the ruby tiger moth and the two analogues **13** and **14**.

This work enables us to demonstrate that aliphatic dithioacetals derived from sugars can be useful precursors for total synthesis of enantiomerically pure compounds.

Although the Wittig reaction has proved to be a very useful process for olefin synthesis, a careful examination of the isolated products must always be undertaken in order to define the purity of the olefin.

Carbon-carbon bond formation using displacement of primary tosylates by organocuprate species is really a useful methodology and we have shown that an epoxy tosylate could be chemoselectively reacted with cyanocuprates.

The overall yield of this ten-step synthesis is 11%.

Experimental

^{1}H-N.m.r. spectra were recorded on Perkin-Elmer R32 and Bruker AM 300 WB instruments. Chemical shifts are reported in ppm downfield from TMS (δ) as an internal standard. The following abbreviations are used for spin multiplicity: s = singlet, d = doublet, dd = doublet of doublet, t = triplet and m = multiplet. ^{13}C-N.m.r. spectra were recorded on a Bruker WP-80 instrument. Mass spectra were determined on a Ribermag R-10-10C instrument in the NH_3 chemical ionization mode. Optical rotations were measured on a Perkin-Elmer Model 141 polarimeter at ambient temperature. IR spectra were recorded on a Philips Pye Unicam SP3-100 spectrophotometer and are reported in wave numbers (cm^{-1}).

Analytical t.l.c. was performed on 0.25 mm pre-coated silica gel plates purchased from E. Merck. Products were purified using the flash chromatography technique on Kieselgel 60 (230-400 mesh ASTM, 0.040-0.063 mm) purchased from E. Merck.

Commercial grade reagents and solvents were used as supplied with the following exceptions: methylene chloride, distilled over phosphorous pentoxide; toluene and hexane, distilled over calcium hydride; ether and tetrahydrofuran (THF), distilled over sodium benzophenone ketyl; dimethyl sulfoxide (DMSO), pyridine, triethylamine and hexamethylphosphoric triamide (HMPA) over calcium hydride.

Every reaction sensitive to oxygen or moisture was conducted under an argon atmosphere.

Elemental analyses were obtained from the Service Central de Micro-Analyse du Centre National de la Recherche Scientifique (Vernaison, France).

D-Xylose diethyl dithioacetal[9,10] 1.

Compound 1 was prepared according to Ref. 10 with the following modification: 40 g of D-Xylose was dissolved in 40 ml of concentrated hydrochloric acid (d = 1.19) and 40 g (47 ml) of ethane thiol was added. When the reaction was over, the mixture was diluted with water (400 ml) and neutralized with ammonium hydroxide solution (30 ml). The aqueous solution was extracted twice with petroleum ether (50 ml), the organic phase containing excess of ethane thiol being discarded. Concentration of the aqueous phase under vacuum gave a crystalline residue which was suspended in a mixture of acetone (400 ml) and ethyl acetate (200 ml). The resulting suspension was filtered over a layer of celite 545. The insoluble mineral material was washed with acetone (300 ml) and the filtrate was concentrated to dryness. The syrup thus obtained (70 g) crystallized on standing in the cold. D-Xylose diethyl dithioacetal was isolated in a nearly quantitative yield in this way and was used without further purification for acetonation.

2,3-4,5-Di-O-isopropylidene-D-xylose diethyl dithioacetal 2.

Crude **1** (70 g, 273 mM) was treated according to Ref. 11. After the work-up, compound **2** was isolated as a clear oil (81 g, 90%) which could be purified by distillation; bp: 128°C/0.05 mm Hg, [lit.[29] 115-120°C/0.02 mm Hg], $[\alpha]_D^{20}$ = -65° (c, 1.91, acetone), [lit.[10] $[\alpha]_D^{18}$ = -62° (c, 2,62, acetone), lit.[30] $[\alpha]_D^{22}$ = -67° (c, 2.80, acetone)].

2-Deoxy-4,5-O-isopropylidene-D-threo-pent-1-enose diethyl dithioacetal 3.

Compound **3** (12.7 g, 45.7 mM) was prepared in 86% yield from purified **2** (17.9 g, 53.2 mM) as described in Ref. 12.

2-Deoxy-4,5-O-isopropylidene-D-threo-pentose diethyl dithioacetal 4.

Method A: Reduction of **3** (9.20 g, 33.0 mM) with $LiAlH_4$ in dry ether was achieved as described in Ref. 12 to give crude compound **4** (9.83 g, 35 mM). Compound **4** was purified by distillation; bp: 106-110°C/0.04 mm Hg (7.89 g, 28.2 mM, 85% yield).

Method B: A 3.4 M solution of Red-Al (54.4 mM, 16 ml, 1.2 eq) was added to a cold solution (0°C) of purified compound **3** (12.67 g, 45.6 mM) in dry toluene in the course of 15 min. After 1 hr at 0°C, the reaction was quenched with a 15% aqueous NaOH solution. The reaction mixture was diluted with ether (400 ml) and the aqueous phase was discarded. The organic phase was washed with water until neutral, brine, then dried over $MgSO_4$. After concentration, crude **4** was isolated and purified by distillation; bp: 106-110°C/0.04 mm Hg, (11.72 g, 42.1 mM, 92%), $[\alpha]_D^{20}$ = +22° (c, 2.07, CH_2Cl_2), [lit.[12] $[\alpha]_D^{23}$ = +25.6° (c, 5.00, $CHCl_3$)].

2-Deoxy-4,5-O-isopropylidene-D-threo-aldehydo pentose 5.

Red mercury (II) oxide (4.3 g, 20 mM, 2 eq), boron trifluoride etherate (2.44 g, 2.4 ml, 20 mM, 2 eq) and 85% aqueous THF (20 ml) were stirred vigorously in a flask. The dithioacetal **4** (2.8 g, 10 mM), dissolved in THF (8 ml) was added (double tip needle) in the course of 15 min under argon. Stirring was continued for 15 min after the addition was complete. During this time the red mercury (II) oxide gradually dissolved. Ethyl ether (120 ml) was added and the reaction mixture was neutralized with anhydrous sodium carbonate (7 g). The salts were removed by filtration through a layer of celite 545, then washed with ethyl ether (200 ml). The filtrate was concentrated to dryness to give a residue which was dissolved in toluene. Insoluble mercury salts were removed by filtration and concentration of the colourless solution gave compound **5** as a syrup (1.70 g). After coevaporation with toluene, the latter was dried under vacuum and was immediately used in the Wittig reaction. Compound **5** exhibited two spots on t.l.c. whose ratio depended on the solvent used. This was probably due to an equilibrium between the aldehydo derivative **5** and a dimerization product[31]. ^{1}H-N.m.r. ($CDCl_3$): 9.79 (1H, t, $J_{1,2} = J_{1,2'} = 1.6$ Hz, H_1); 2.60 (2H, m, H_2 and $H_{2'}$); 1.45 and 1.35 (6H, 2s, isopropylidene CH_3); i.r. (neat): 3650-3300 (broad, OH), 1725 (CHO), 1380 and 1370 (isopropylidene); m.s. ($C_8H_{14}O_4$, M.W. = 174): 174 (76), 192 (7).

1,2-O-Isopropylidene-5Z-undecen-1,2R,3R-triol 7a.

n-Hexyl triphenyl phosphonium bromide[32] (17 g, 40 mM, 4 eq) and sodium amide (1.56 g, 40 mM, 4 eq) were suspended in dry THF (60 ml). Dry HMPA (8 ml) was added and the suspension was stirred for 90 min at room temperature. The deep orange solution of the ylide was then cooled to -70°C and the aldehyde **5** (1.7 g, 10 mM in 10 ml of dry THF) was added dropwise (double tip needle) for 15 min. The suspension was allowed to warm up to room temperature. The reaction mixture (pale yellow) was concentrated under vacuum and the residue was suspended in hexane (50 ml). This suspension was then filtered through a layer of silica gel. After elution (hexane-ethyl acetate 4:1, 300 ml), the filtrate was concentrated to dryness to give a coloured syrup. Purification by flash chromatography (SiO_2:50 g, elution with hexane-ethyl acetate 4:1 containing 0.1% Et_3N) afforded:

a. **1,2-O-Isopropylidene-3E,5Z-undecadien-1,2R-diol 6.** (125 mg, 6%); bp: 60°C/0.09 mm Hg; $[\alpha]_D^{20}$ = +4° (c, 1.42, CCl_4); n.m.r. ($CDCl_3$): 6.58 (1H, dd, $J_{4,3}$ = 15.0 Hz, $J_{4,5}$ = 10.3 Hz, $J_{4,2}$ = $J_{4,6}$ = 1.0 Hz, H_4); 5.97 (1H, dd, $J_{5,6}$ = $J_{5,4}$ = 10.3 Hz, J_5, CH_2 = 1.0 Hz, H_5); 5.59 (1H, dd, $J_{3,2}$ = 8.0 Hz, H_3); 5.48 (1H, dd, J_6, CH_2 = 7.3 Hz, H_6); 4.57 (1H, broad ddd, $J_{2,3}$ = $J_{2,1}$ = 8.0 Hz, $J_{2,1}$ = 6.0 Hz, H_2); 4.08 (1H, dd, $J_{1,1'}$ = 8.0 Hz, H_1); 3.59 (1H, dd, $H_{1'}$); 2.18 (2H, broad m, CH_2); 1.45 and 1.41 (6H, 2s, isopropylidene CH_3); 1.40-1.20 (6H, m, $[CH_2]_3$); 0.92 (3H, broad t, CH_3). In C_6D_6 solution, the following chemical shifts were observed: 6.58 (H_4); 5.98 (H_5); 5.55 (H_3); 5.42 (H_6); 4.43 (H_2); 3.85 (H_1); 3.44 ($H_{1'}$); 2.08 ($^7CH_2$)*; 1.42 and 1.38 (isopropylidene CH_3); 1.35-1.15 ($[CH_2]_3$); 0.88 (CH_3); m.s. ($C_{14}H_{24}O_2$, M.W. = 224): 167 (100) ($[M+1] - C_3H_6O$), 224 (21), 225 (5); Anal. calcd. for $C_{14}H_{24}O_2$: C, 74.95; H, 10.78; found: C, 74.51; H, 10.79.

b. Compound **7a**, colourless liquid (1.73 g, 71%); bp: 70°C/0.1 mm Hg; $[\alpha]_D^{20}$ = +8° (c, 1.35, CCl_4); ^{1}H-n.m.r. (300 MHz, $CDCl_3$): 5.55 (1H, m, $J_{6,5}$ = 11.0 Hz, J_6, $^7CH_2$ = 6.7 Hz, J_6, $^4CH_2$ = 1.3 Hz, H_6); 5.42 (1H, m, J_5, $^4CH_2$ = 6.6 Hz, J_5, $^7CH_2$ = 1.3 Hz, H_5); 4.07 - 3.98 (2H, m, H_1 and H_2); 3.77 (1H, dd, $J_{1',1}$ = 12.2 Hz, $J_{1',2}$ = 3.2 Hz, $H_{1'}$); 3.55 (1H, td, J_3, $^4CH_2$ = 9.0 Hz, $J_{3,2}$ = 5.6 Hz, H_3); 2.23 (2H, m, $^4CH_2$); 2.04 (2H, td, J $^7CH_2$, $^8CH_2$ = 6.7 Hz, $^7CH_2$); 1.59 (1H, s, OH); 1.44 and 1.37 (6H, 2s, isopropylidene CH_3); 1.33 - 1.28 (6H, m, $[CH_2]_3$); 0.88 (3H, t, J CH_3, CH_2 = 6.7 Hz, CH_3); ^{13}C-n.m.r. ($CDCl_3$): 133.4 and 124.3 (sp^2 C); 109.4 (C'_1); 78.5 (C_2); 72 (C_3); 66.3 (C_1); 31.9 (C_4); 31.6 (C_8); 29.4 (C_9); 27.5 (C_7); 26.7 and 25.4 (isopropylidene CH_3); 22.6 (C_{10}); 14.1 (C_{11}). After 45 hr, migration of the isopropylidene protecting group had occurred, giving a mixture (1:1) of 1,2- and 2,3-O-isopropylidene derivatives; CH_2OH gave a resonance at δ:62.3 ppm (C_1); i.r. (neat): 3600 - 3200 (broad, OH); m.s. ($C_{14}H_{26}O_3$, M.W. = 242): 185 (100) ($[M+1] - C_3H_6O$), 243 (50), 260 (3); Anal. calcd. for $C_{14}H_{26}O_3$: C, 69.38; H, 10.81; found: C, 69.56; H, 10.79.

Acetylation (pyridine, acetic anhydride) of compound **7a** yielded compound **7b** homogeneous on t.l.c. which was subjected to a careful analysis. $[\alpha]_D$ = -9° (c, 2.02, CCl_4); ^{1}H-n.m.r. (300 MHz, $CDCl_3$): 5.50 (1H, m, $J_{6,5}$ = 11.0 Hz, J_6, $^7CH_2$ = 7.0 Hz, J_6, $^4CH_2$ = 1.2 Hz, H_6); 5.32 (1H, m, J_5, $^4CH_2$ = 7.0 Hz, J_5, $^7CH_2$ = 1.3 Hz, H_5); 4.94 (1H, td, J_3, $^4CH_2$ = 6.7 Hz, $J_{3,2}$ = 5.2 Hz, H_3); 4.19 (1H, ddd, $J_{2,1}$ = $J_{2,1'}$ = 6.7 Hz, H_2); 4.00 (1H, dd, $J_{1,1'}$ = 8.5 Hz, H_1); 3.72 (1H, ddd, $H_{1'}$); 2.36 (2H, dd, J_3, $^4CH_2$ = J_5, $^4CH_2$ = 6.7 Hz, $^4CH_2$); 2.08 (3H, s, $OCO\underline{CH_3}$); 2.03 (2H, td, J_6, $^7CH_2$ = J $^7CH_2$, $^8CH_2$ = 7.0 Hz, $^7CH_2$); 1.43 and 1.35 (6H, 2s, isopropylidene CH_3); 1.50 - 1.24 (6H, m, $[CH_2]_3$); 0.89 (3H, t, J CH_3, CH_2 = 6.7 Hz, CH_3); E-isomer could not be detected by examination of this spectrum. A G.C./M.S. experiment was undertaken: compound **7b** exhibited two peaks in a 92:8 Z/E ratio (chemical bonded Sil-5 capillary column); m.s. ($C_{16}H_{28}O_4$, M.W. = 234): 227 (100) ($[M+1] - C_3H_6O$), 285 (25), 302 (2); ^{13}C-n.m.r. ($CDCl_3$): 170.6 (CO); 134.6 and 124.2 (sp^2 C of the E-isomer); 133.5 and 123.5 (sp^2 C of the Z-isomer); 109.6 (C'_1); 76.2 (C_2); 73.1 (C_3); 65.8 (C_1); 34.3 (C_4 of the E-isomer); 32.6 (C_7 of the E-isomer); 31.6 (C_8); 31.4 (C_8 of the E-isomer); 29.3 (C_9); 28.9 (C_4 of the Z-isomer); 27.3 (C_7 of the Z-isomer); 26.4 and 25.6 (isopropylidene CH_3); 22.6 (C_{10}); 21.2 (acetate CH_3); 14.1 (C_{11}); i.r. (neat): 1730 and 1230 (OCO); 1360 (isopropylidene); Anal. calcd. for $C_{16}H_{28}O_4$: C, 67.57; H, 9.93; found: C, 67.11; H, 10.16.

1,2-O-Isopropylidene-3-O-methanesulfonyl-5Z-undecen-1,2R,3R-triol 8a.

To a cold solution (0°C) of compound **7a** (2.13 g, 8.80 mM) in pyridine (15 ml) was added freshly distilled methanesulfonyl chloride (1.0 ml, 1.5 eq). After 1 hr, the excess reagent was destroyed by adding ice chips. The reaction mixture was diluted with ether (200 ml) and the organic phase was successively washed with aqueous potassium hydrogen sulfate, water, aqueous sodium hydrogen carbonate, water, brine then dried over $MgSO_4$. Concentration of the solution afforded pure mesylate **8a** as a mobile oil (2.7 g, 96%); $[\alpha]_D^{20}$ = -13° (c, 2.05, CCl_4); n.m.r.(300 MHz, $CDCl_3$): 5.59 (1H, m, $J_{6,5}$ = 11.0 Hz, J_6, $^7CH_2$ = 7.1 Hz, H_6);

*Superior figures refer to the number of the carbon atom in question.

5.40 (1H, m, J_5, $^4CH_2$ = 6.5 Hz, J_5, $^7CH_2$ = 1.6 Hz, H_5); 4.63 (1H, td, $J_{3,2}$ = J_3, $^4CH_2$ = 6.5 Hz, H_3); 4.23 (1H, ddd, $J_{2,3}$ = $J_{2,1}$ = $J_{2,1'}$ = 6.5 Hz, H_2); 4.05 (1H, dd, $J_{1,1'}$ = 8.7 Hz, H_1); 3.80 (1H, ddd, $H_{1'}$); 3.08 (3H, s, CH_3SO_3); 2.46 (2H, dd, $^4CH_2$); 2.04 (2H, td, J $^7CH_2$, $^8CH_2$ = 7.1 Hz, $^7CH_2$); 1.44 and 1.36 (6H, 2s, isopropylidene CH_3); 1.34 - 1.27 (6H, m, $[CH_2]_3$); 0.89 (3H, t, J CH_3, CH_2 = 6.7 Hz, CH_3); i.r. (neat): 1370 and 1180 (OSO_2); m.s. ($C_{15}H_{28}O_5S$, M.W. = 320): 225 (35) ([M]) - CH_3O_3S), 321 (86), 338 (100); Anal. calcd. for $C_{15}H_{28}O_5S$: C, 56.22; H, 8.81; found: C, 56.43; H, 9.08.

1,2-O-Isopropylidene-3-O-p-toluenesulfonyl-5Z-undecen-1,2R,3R-triol 8b.

Tosylation of compound **7a** (692 mg, 2.86 mM) was achieved in pyridine (5 ml) in the presence of 4-dimethylaminopyridine [DMAP] (350 mg, 2.86 mM, 1 eq) and p-toluenesulfonyl chloride (820 mg, 3.3 mM, 1.15 eq) at room temperature. After 24 hr, classical work-up afforded crude tosylate **8b**. Purification by silica gel column (eluted with hexane-ethyl acetate 4:1) yielded pure syrupy **8b** (855 mg, 75%), $[\alpha]_D^{20}$ = -9° (c, 2.09, CCl_4); n.m.r. (300 MHz, $CDCl_3$): 7.80 (2H, d, aromatic H); 7.31 (2H, d, aromatic H); 5.42 (1H, m, $J_{6,5}$ = 11.0 Hz, J_6, $^7CH_2$ = 6.8 Hz, $J_{6,4}$ = $J_{6,4'}$ = 1.4 Hz, H_6); 5.20 (1H, m, $J_{5,4}$ = $J_{5,4'}$ = 7.4 Hz, J_5, $^7CH_2$ = 1.4 Hz, H_5); 4.50 (1H, ddd, $J_{3,4}$ = $J_{3,4'}$ = 6.8 Hz, $J_{3,2}$ = 4.8 Hz, H_3); 4.23 (1H, ddd, $J_{2,1}$ = $J_{2,1'}$ = 6.7 Hz, H_2); 3.96 (1H, dd, $J_{1,1'}$ = 8.7 Hz, H_1); 3.80 (1H, dd, $H_{1'}$); 2.50 (1H, ddd, $J_{4,4'}$ = 13.2 Hz, H_4); 2.44 (3H, s, tosyl CH_3); 2.35 (1H, ddd, $H_{4'}$); 1.93 (2H, td, J $^7CH_2$, $^8CH_2$ = 6.8 Hz, $^7CH_2$); 1.31 and 1.28 (6H, 2s, isopropylidene CH_3); 1.26 - 1.21 (6H, m, $[CH_2]_3$); 0.88 (3H, t, J CH_3, CH_2 = 6.7 Hz, CH_3); i.r. (neat): 1370 and 1190 (OSO_2); m.s. ($C_{21}H_{32}O_5S$, M.W. = 396): 225 (100) ([M] -$C_7H_7O_3S$), 397 (82), 414 (73); Anal. calcd. for $C_{21}H_{32}O_5S$: C, 63.60; H, 8.13; found: C, 63.58; H, 7.89.

(5Z)-cis-2R,3S-Epoxyundecen-1-ol 9.

To a cold solution (0°C) of mesylate **8a** (2.7 g, 8.4 mM) in methanol (30 ml) was added in one portion p-toluenesulfonic acid monohydrate (2.24 g, 11.8 mM, 1.4 eq). The homogeneous solution was stirred for 2 hr after which time the starting material had disappeared. Dichloromethane (30 ml) was added and 1M sodium methanolate in methanol was added (13 ml, 13 mM). Stirring was continued at 0°C for 2 hr. The reaction mixture was then concentrated under vacuum and the residue was suspended in ether (200 ml). Inorganic material was extracted with aqueous saturated sodium dihydrogen phosphate. The organic phase was then washed with brine, dried over $MgSO_4$ and concentrated to give crude epoxy alcohol **9**. Purification of compound **9** was achieved by flash chromatography (elution with hexane-ethyl acetate 7:3) to afford pure epoxide (1.35 g, 86%) which was distilled (1.20 g, 77%); bp: 73°C/0.15 mm Hg, $[\alpha]_D^{20}$ = +11° (c, 2.60, CCl_4), n.m.r. (300 MHz, $CDCl_3$): 5.55 (1H, m, $J_{6,5}$ = 11.0 Hz, J_6, $^7CH_2$ = 7.2 Hz, $J_{6,4}$ = $J_{6,4'}$ = 1.6 Hz, H_6); 5.40 (1H, m, $J_{5,4'}$ = 7.2 Hz, $J_{5,4}$ = 6.6 Hz, J_5 $^7CH_2$ = 1.4 Hz, H_5); 3.86 (1H, ddd, $J_{1,1'}$ = 12.3 Hz, J_1, OH = 5.8 Hz, $J_{1,2}$ = 4.2 Hz, H_1); 3.74 (1H, ddd, $J_{1',2}$ = 6.9 Hz, $J_{1'}$, OH = 5.8 Hz, $H_{1'}$); 3.16 (1H, ddd, $J_{2,3}$ = 4.3 Hz, H_2); 3.05 (1H, ddd, $J_{3,4}$ = 7.2 Hz, $H_{3,4'}$ = 6.5 Hz, H_3); 2.43 (1H, ddd, $J_{4,4'}$ = 15.0 Hz, H_4); 2.21 (1H, ddd, $H_{4'}$); 2.03 (2H, td, J $^7CH_2$, $^8CH_2$ = 7.2 Hz, $^7CH_2$); 1.70 (1H, dd, OH); 1.48 - 1.27 (6H, m, $[CH_2]_3$); 0.89 (3H, t, J CH_3, CH_2 = 6.7 Hz, CH_3); ^{13}C-n.m.r. ($CDCl_3$): 133.3 and 123.4 (sp^2 C); 60.9 (C_1); 56.8 (C_2 and C_3); 31.6 (C_8), 29.3 (C_9); 27.5 (C_7); 26.5 (C_4); 22.6 (C_{10}); 14.1 (C_{11}); in the presence of the relaxation reagent Cr $(Acac)_3$: 132.9 and 123.1 (sp^2 C); 60.7 (C_1); 56.6 and 56.3 (C_2, C_3); 31.2 (C_8); 28.9 (C_9); 27.1 (C_7); 26.1 (C_4); 22.2 (C_{10}); 13.7 (C_{11}); i.r. (neat): 3600 - 3200 (broad, OH); m.s. ($C_{11}H_{20}O_2$, M.W. = 184): 185 (78), 202 (100). It was impossible to get a correct micro analysis for this compound.

Epoxy alcohol **9** was prepared in the same manner as described above starting from tosylate **8b**. HRMS: MH^+ 185.15427 ($C_{11}H_{20}O_2$ requires 185.15415).

(5Z)-cis-2R,3S-Epoxy-1-O-p-toluenesulfonyl-undecen-1-ol 10.

p-Toluenesulfonyl chloride (2.48 g, 13.0 mM, 2 eq) was added to a solution of compound **9** (1.20 g, 6.52 mM) in dry pyridine (5 ml) with stirring and ice-cooling. Stirring was continued overnight at 3°C. The reaction mixture was poured into ice-water and extracted with ether. The ether solution was washed successively with aqueous saturated potassium hydrogen sulfate, water, aqueous sodium hydrogen carbonate, water, brine then dried over $MgSO_4$ and concentrated to afford a crude mixture of products **10** and **11**.

Flash chromatography (elution with hexane-ethyl acetate 9:1) afforded:

a. **(5Z)-cis-2R,3S-Epoxyundecen-1-yl-chloride** 11 (102 mg, 8%); bp: 100°C/5 mm Hg; $[\alpha]_D^{20}$ = -20° (c, 2.41, CCl_4); n.m.r. (300 MHz, $CDCl_3$): 5.55 (1H, m, $J_{6,5}$ = 11.3 Hz, J_6, $^7CH_2$ = 7.1 Hz, $J_{6,4}$ = $J_{6,4'}$ = 1.2 Hz, H_6); 5.42 (1H, m, $J_{5,4}$ = $J_{5,4'}$ = 7.0 Hz, J_5, $^7CH_2$ = 1.0 Hz, H_5); 3.70 (1H, dd, $J_{1,1'}$ = 11.5 Hz, $J_{1,2}$ = 6.0 Hz, H_1); 3.51 (1H, dd, $J_{1',2}$ = 6.6 Hz, $H_{1'}$); 3.25 (1H, ddd, $J_{2,3}$ = 4.0 Hz, H_2); 3.08 (1H, ddd, $J_{3,4}$ = $J_{3,4'}$ = 6.3 Hz, H_3); 2.42 (1H, ddd, $J_{4,4'}$ = 15.5 Hz, H_4); 2.24 (1H, ddd, $H_{4'}$); 2.05 (2H, td, J $^7CH_2$, $^8CH_2$ = 7.1 Hz, $^7CH_2$); 1.55 - 1.23 (6H, m, $[CH_2]_3$); 0.89 (3H, t, J CH_3, CH_2 = 6.7 Hz, CH_3); m.s. ($C_{11}H_{19}ClO$, M.W. = 202): 202 (5), 203 (19), 220 (100); Anal. calcd. for $C_{11}H_{19}ClO$: C, 65.17; H, 9.45; found: C, 64.90; H, 9.47.

b. Pure tosylate **10** as a mobile oil (1.31 g, 60%); $[\alpha]_D^{20}$ = +29° (c, 3.40, CCl_4); n.m.r. (300 MHz, $CDCl_3$): 7.82 (2H, d, aromatic H); 7.36 (2H, d, aromatic H); 5.53 (1H, m, $J_{6,5}$ = 11.0 Hz, J_6, $^7CH_2$ = 7.0 Hz, $J_{6,4}$ = $J_{6,4'}$ = 1.0 Hz, H_6); 5.33 (1H, m, $J_{5,4}$ = $J_{5,4'}$ = 6.8 Hz, J_5, $^7CH_2$ = 1.0 Hz, H_5); 4.22 (1H, dd, $J_{1,1'}$ = 11.8 Hz, $J_{1,2}$ = 5.1 Hz, H_1); 4.11 (1H, dd, $J_{1',2}$ = 6.3 Hz, $H_{1'}$); 3.17 (1H, ddd, $J_{2,3}$ = 4.2 Hz, H_2); 2.99 (1H, ddd, $J_{3,4}$ = $J_{3,4'}$ = 6.8 Hz, H_3); 2.46 (3H, s, tosylate CH_3); 2.31 (1H, ddd, $J_{4,4'}$ = 15.3 Hz, H_4); 2.11 (1H, ddd, $H_{4'}$); 1.98 (2H, td, J $^7CH_2$, $^8CH_2$ = 7.0 Hz, $^7CH_2$); 1.39 - 1.21 (6H, $[CH_2]_3$); 0.89 (3H, t, J CH_3, CH_2 = 6.8 Hz); i.r. (neat): 1370 and 1190 (OSO_2); m.s. ($C_{18}H_{26}O_4S$, M.W. = 338): 356 (100); Anal. calcd. for $C_{18}H_{26}O_4S$: C, 63.87; H, 7.74; found: C, 63.66; H, 7.94.

Carbon-carbon bond formation using organocuprate reagents: general procedure.

n-Butyl lithium solution in hexane was purchased from Janssen. n-Decyl lithium solution in hexane was prepared from freshly distilled n-decyl chloride and lithium wire according to Ref. 33 and used immediately. n-Butyl lithium was titrated just prior to being used with 2,5-dimethoxybenzyl alcohol[34] in THF while n-decyl lithium was titrated prior to being used with 1,10-phenantroline[35]. Lithium di-n-butylcuprate and lithium di-n-decylcuprate were prepared and reacted in dry ether at -30°C according to C.R. Johnson[25]. Dilithium-di-n-butyl-cyanocuprate and dilithium-di-n-decyl-cyanocuprate were prepared and reacted in dry T.H.F as described in Ref. 28.

Method A[25]: Tosylate **10** (1eq) in dry ether was added dropwise via a double tip needle under argon to a solution of the suitable cuprate (3 to 5 eq) in dry ether at -30°C. This temperature was maintained during the course of the reaction (15 hr). After this time, the reaction mixture was quenched with saturated aqueous NH_4Cl and diluted with ether. The organic phase was washed with brine then dried ($MgSO_4$) and concentrated to give a crude residue which was purified by flash chromatography (elution with hexane-ether 98:2).

Method B[28]: Tosylate **10** (1 eq) in dry THF was added dropwise via a double tip needle under argon to a slurry of the suitable cyanocuprate (3 to 5 eq) in dry THF at -30°C. The reaction mixture was warmed to -10°C then maintained at -10°C during the course of the reaction (15 hr) after which time it was quenched with saturated aqueous NH_4Cl containing NH_4OH (10%). Extractive work-up and purification were conducted as described above.

(6Z)-cis-9S,10R-Epoxyheneicosene III (compound 12).

Method A: Reaction of **10** with n-Dec_2CuLi (4 eq) lead to the epoxide **12** in 14% yield. Further elution with hexane-ethyl acetate 9:1 gave the two alcohols resulting from the opening of the epoxide ring (43%) and a third one, identified with (1,5Z)-undecadien-3S-ol[36] (18%).

Method B: Reaction of **10** with n-$Dec_2CuCNLi_2$ (5 eq) lead to epoxide **12** in 44% yield as a mobile liquid; bp: 155-160°C/1 mm Hg; $[\alpha]_D^{20}$ = +5.5° (c, 5.00, CCl_4); n.m.r. (300 MHz, $CDCl_3$): 5.53 (1H, m, $J_{6,7}$ = 11.0 Hz, J_6, $^5CH_2$ = 7.0 Hz, $J_{6,8}$ = $J_{6,8'}$ = 1.2 Hz, H_6); 5.41 (1H, m, $J_{7,8}$ = $J_{7,8'}$ = 6.4 Hz, J_7, $^5CH_2$ = 1.2 Hz, H_7); 2.92 (2H, unresolved system, H_9 and H_{10}); 2.38 (1H, ddd, $J_{8,8'}$ = 14.0 Hz, $J_{8,9}$ = 6.2 Hz after H_7 irradiation, H_8); 2.19 (1H, ddd, $H_{8'}$); 2.03 (2H, td, J $^5CH_2$, $^4CH_2$ = 7.0 Hz, $^5CH_2$); 1.53 (2H, m, $^{11}CH_2$); 1.40 - 1.15 (24H, m, $[CH_2]_{12}$); 0.91 (6H, m, 2xCH_3); i.r. (neat): 2960, 2930, 2860, 1460, 1380;

m.s. ($C_{21}H_{40}O$; M.W. = 308): 183 (2.1) ($C_{12}H_{23}O$); m.s. (Nitrogen Oxide chemical ionization mode): 110 (C_8H_{14}), 139 ($C_9H_{15}O$), 183 ($C_{12}H_{23}O$), 308 (M), 309 (M+1), 338 (M+NO); HRMS: MH^+ 309.31588 ($C_{21}H_{41}O$ requires 309.31572).

An analytical sample of E-isomer could be obtained from a G.C. split experiment (25 m W COT, 0.22 i.d.; CPSIL 5 CB, 240°C, p He = 0.5 b); n.m.r. (300 MHz, $CDCl_3$): 5.56 (1H, td, $J_{6,7}$ = 15.5 Hz, $J_{6,}{}^5CH_2$ = 6.5 Hz, H_6); 5.42 (1H, ddd, $J_{7,8} = J_{7,8'}$ = 6.5 Hz, H_7); 2.90 (2H, unresolved system, H_9 and H_{10}); 2.35 (1H, ddd, $J_{8,8'}$ = 14.0 Hz, H_8); 2.15 (1H, ddd, $H_{8'}$); 2.01 (2H, td, J $^5CH_2$, $^4CH_2$ - 6.5 Hz, $^5CH_2$); 1.45 - 1.10 (26H, m, $[CH_2]_{13}$); 0.88 (6H, m, $2xCH_3$).

The mixture of opening products of the epoxide ring was isolated in 20% yield; n.m.r. (300 MHz, $CDCl_3$): 5.56 (1H, m, H_6); 5.40 (1H, m, H_7); 3.61 (1H, broad s, H_9 or H_{10}); m.s. ($C_{31}H_{62}O$, M.W. = 450): 450 (60), 451 (55), 468 (10).

(6Z)-cis-9S,10R,-Epoxypentadecene 13.

Method A: Reaction of epoxy tosylate **10** with n-Bu_2CuLi (4 eq) gave epoxide **13** in 62% yield as a mobile liquid; bp: 100-105°C/5 mm Hg; $[\alpha]_D^{20}$ = +7° (c, 0.80, CCl_4); n.m.r. (300 MHz, $CDCl_3$): 5.53 (1H, m, $J_{6,7}$ = 10.5 Hz, $J_{6,}{}^5CH_2$ = 7.4 Hz, $J_{6,8} = J_{6,8'}$ = 1.2 Hz, H_6); 5.42 (1H, m, $J_{7,8} = J_{7,8'}$ = 6.8 Hz, $J_{7,}{}^5CH_2$ = 1.2 Hz, H_7); 2.93 (2H, unresolved system, H_9 and H_{10}); 2.38 (1H, ddd, $J_{8,8'}$ = 14.2 Hz, $J_{8,9}$ = 6.2 Hz after H_7 irradiation, H_8); 2.18 (1H, ddd, $J_{8',9}$ - 6.2 Hz, $H_{8'}$); 2.05 (2H, td, J $^5CH_2$, $^4CH_2$ = 7.4 Hz, $^5CH_2$); 1.46 (2H, m, $^{11}CH_2$); 1.39 - 1.25 (12H, m, $[CH_2]_6$); 0.90 (6H, m, $2xCH_3$); ^{13}C-n.m.r. ($CDCl_3$): 132.8 (sp^2 C); 124 (sp^2 C); 57.3 and 56.6 (C_9 or C_{10}); 31.9 (C_8); 31.6 (C_4); 29.4 (C_3); 27.9 (1C); 27.6 (C_5); 26.4 (2C); 22.6 (2C); 14.1 (2C). This ^{13}C-n.m.r. spectrum revealed the presence of three small signals at 133.5, 124.8 (sp^2 carbons of the E-isomer) and 32.7 ppm with intensities of about 6% of those of the major signals. This implies that the Z-isomeric purity of synthetic **13** is about 91%. This value was corroborated by a G.C. analysis. m.s. ($C_{15}H_{28}O$, M.W. - 224): 224 (9), 225 (100), 242 (19) HRMS: MH^+ 225.22408 ($C_{15}H_{29}O$ requires 225.22183).

Method B: Reaction of epoxy tosylate **10** with n-$Bu_2CuCNLi_2$ gave epoxide **13** in 52% yield together with 24% of unreacted starting material. The compound thus obtained was identical with the product previously described.

cis-6R,7S-Epoxypentadecane 14.

A solution of compound **13** in dry toluene (50 mg, 0.22 mM) was hydrogenated over Adams catalyst (5 mg) for 30 min after which time the starting material was transformed (compounds **13** and **14** had the same Rf on t.l.c.; hexane-ether 95:5; but compound **14** gave a negative test with a 10% $KMnO_4$ solution in aqueous 1N H_2SO_4). The catalyst was removed by filtration and the filtrate was concentrated to dryness. Flash chromatography purification (elution with hexane-ether 98:2) yielded the saturated aliphatic epoxide **14** (41 mg, 79%) as a mobile liquid; $[\alpha]_D^{20}$ = -1° (c, 4.07, CCl_4); n.m.r. (300 MHz, $CDCl_3$): 2.90 (2H, unresolved system, H_6 and H_7); 1.65 - 1.20 (22H, m, $[CH_2]_{11}$); 0.90 (6H, m, $2xCH_3$); m.s. ($C_{15}H_{30}O$, M.W. = 226): 113 (74) (C_8H_{17}), 155 (87) ($C_{10}H_{19}O$), 227 (22), 244 (82); Anal. calcd. for $C_{15}H_{30}O$: C, 79.57; H, 13.36; found: C, 79.46; H, 13.32.

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