Chemistry of Insect Antifeedants from *Azadirachta indica* (Part 12):[1] Use of Silicon as a Control Element in the Synthesis of a Highly Functionalized Decalin Fragment of Azadirachtin

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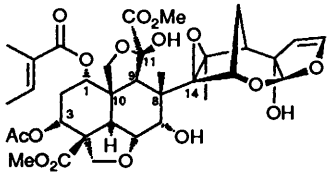
A diastereoselective synthesis of a highly functionalized decalin fragment **61** of the insect antifeedant azadirachtin **1** is described. An intramolecular Diels–Alder reaction of triene **15** and subsequent intramolecular aldol reaction were employed to assemble the basic carbon skeleton. A high degree of stereocontrol in the cycloaddition step was achieved by using a dimethyl(phenyl)silyl group to effect *endo*-selectivity. The silyl group enabled further diastereoselective elaboration and later stereospecific introduction of C(3)† hydroxy functionality through oxidation with peracid. Both enantiomers of the intermediate alcohol **40** were obtained by optical resolution. The C(9)–C(10) tetrahydrofuran hemiketal moiety was introduced using a novel 6→5 ring-contraction protocol with initial formation of the δ-lactone **49** by an intramolecular Michael addition. Subsequent α-hydroxylation and methanolysis furnished the tetrahydrofuran hemiketal **50**, which was converted in two steps into the fully protected enantiopure target molecule **61**. Single-crystal X-ray analyses of compounds **18**, **50**, and (+)-**53** have been carried out and the absolute configuration of compound (+)-**53** determined

The natural product azadirachtin **1** isolated from the Indian neem tree *Azadirachta indica* A. Juss (Meliaceae)[2] has been recognized as providing an exciting opportunity for insect pest control.[3] Its known behaviour-modifying and antifeedant effects and its growth-regulatory properties can be harnessed in integrated pest-management programmes.[4] Furthermore, its low mammalian toxicity, biodegradability and species selectivity become especially important as a consequence of our need for improved, environmentally acceptable methods of pest control. Azadirachtin displays a broad spectrum of activity against pest insects but does not seriously affect beneficial species, *e.g.* pollinating bees or earthworms.

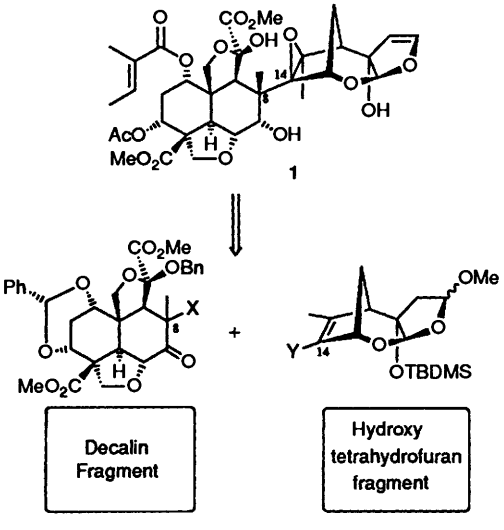


1 Azadirachtin

Additionally, azadirachtin **1** is systematic in plants through translocation to the leaves and growing parts, thus providing an enhanced element of protection. The fact that azadirachtin shows a multitude of biological effects in insects suggests that resistance problems might also be reduced. Taken together these promising results make azadirachtin and related compounds interesting for further study and for potential commercial development.[5] Following the structure determination of azadirachtin **1** independently by our group[6] and by the team in Hohenheim[7] we have begun a detailed investigation of the synthesis, structure–activity relationships and the preparation of azadirachtin mimics.[8] The aim of this work is to devise synthetic strategies to these compounds, since their biological evaluation may yield insight into fundamental feeding processes, host plant recognition, and growth development by insects at a molecular level.

In this paper we address the problem of construction of the major decalin portion of compound **1** in a fully functionalized form suitable for total synthesis and biological studies.[9] Azadirachtin presents a formidable challenge to synthetic chemists[10] in that it contains a densely packed array of 16 stereogenic centres, seven of which are quaternary, and a plethora of different oxygen-containing functional groups. Additionally, it is labile to both acid and base and is also somewhat photosensitive and therefore requires very carefuly manipulation. The approach we have adopted for the synthesis envisages a late coupling of two advanced fragments, a decalin portion and a suitably protected hydroxytetrahydrofuran unit by formation of the linking, hindered C(8)–C(14) bond (Scheme 1).

We recognize that this strategy will necessitate the formation of one of the most difficult bonds in azadirachtin **1** but therein



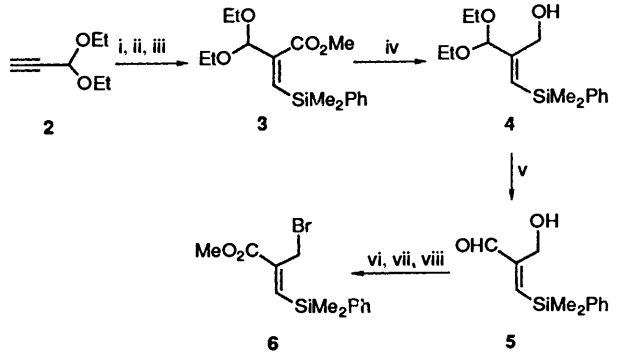
Scheme 1

† Natural product numbering.

lies a challenge. We have already defined an efficient route to the enantiomerically pure right-hand hydroxytetrahydrofuran fragment[11] and have shown that the choice of protection and substituents are compatible with later proposed synthetic steps. Model studies for the elucidation of the coupling reactions are currently underway. Here we report in full on the preparation of the required decalin unit.

Previously we have demonstrated the viability of an intramolecular Diels–Alder process for the formation of a decalin fragment.[12] However, difficulties experienced in the further introduction of the necessary oxygen substituents[13] have caused us to refine our approach and the solution to these problems is reported here. At this stage, it is pertinent to point out the key features of the new approach as these design elements were crucial to the success of the project. Moreover, we believe the chemistry which has been developed could have wider ranging application to other synthetic programmes. A pivotal role was played by the dimethyl(phenyl)silyl group in that it controlled the stereochemical course of the intramolecular Diels–Alder reaction and subsequent processes and finally unveiled itself as a hydroxy group through a silyl-Baeyer–Villiger reaction.[14] The other feature of the synthesis worthy of preliminary comment is the new way in which we have constructed the inherent substituted tetrahydrofuran hemiketal unit by utilizing a novel 6→5 ring-contraction process, the initial ring formation involving an intramolecular Michael addition to an octalone (octahydronaphthalenone) intermediate.

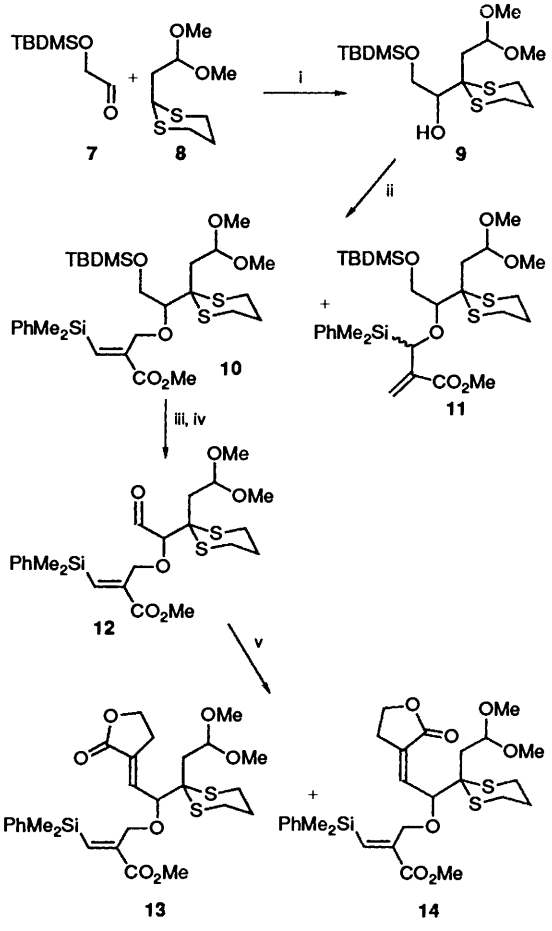
In analogy to previous model work we envisaged constructing the A-ring and fused cyclic ether by an intramolecular Diels–Alder (IMDA) reaction with control of stereochemistry appropriate to the natural product.[12] A very careful analysis of the subtle influence of the triene substituents on the stereochemistry of the proposed IMDA reaction led to the design of the synthetic scheme outlined in the following paragraphs. A detailed account of this analysis which considered the influence of twist-asynchronicity and steric interactions between substituents of the diene and dieneophile parts and the linking chain of the triene on the relative energies of the diastereotopic transition states is provided in the following paper.[15] The preparation of the dienophile fragment **6** of the proposed IMDA precursor is shown in Scheme 2. The synthesis progresses from the known propargylic acetal **2** by way of a three-component coupling sequence to enoate **3**, involving stereospecific and regioselective addition of Fleming's dimethyl(phenyl)silylcuprate,[16] with subsequent carboxylation using CO_2 and final methylation with dimethyl sulfate. This 'one-pot' process proceeded in excellent overall yield. Following



Scheme 2 *Reagents and conditions:* i, $(PhMe_2Si)_2CuLi$·LiCN, THF, −78 °C, 2 h; ii, CO_2, $P(OEt)_3$, −70 °C to room temp., 24 h; iii, $(MeO)_2SO_2$, room temp., 34 h (80% over 3 steps); iv, DIBAL, THF, −25 °C, 12 h; v, PTSA, 2% water–acetone (77% over 2 steps); vi, $NaClO_2$, 2-methylbut-2-ene, Bu^{t}OH–water, 0 °C to room temp., 1.5 h; vii, CH_2N_2, CH_2Cl_2 (94% over 2 steps); viii, NBS, PPh_3, CH_2Cl_2 (69%)

reduction of enoate **3** with diisobutylaluminium hydride (DIBAL) in tetrahydrofuran (THF) to allylic alcohol **4**, acid-mediated acetal cleavage in aq. acetone gave the aldehyde **5**. This was then efficiently converted into the bromo ester **6** by sodium chlorite oxidation,[17] methylation of the resulting acid with diazomethane and reaction with *N*-bromosuccinimide (NBS) and triphenylphosphine under standard conditions.[18]

The coupling partner for enoate **6**, *i.e.* the secondary alcohol **9**, was obtained from the protected hydroxy aldehyde **7*** by reaction with the anion derived from the dithiane **8**[12] (Scheme 3). Treatment of the alcohol **9** with potassium hydride in THF



Scheme 3 *Reagents and conditions:* i, **8**, BuLi, *N,N,N′,N′*-tetramethylethylenediamine, THF, −30 °C, 90 min; then **7**, 5 min (54%); ii, **9**, KH, THF, room temp., 60 min; then **6** at 0 °C to room temp., 30 min (60% of **10** and 18% of **11**); iii, HF, pyridine, MeCN, room temp. to 35 °C, 34 h (85%); iv, DMSO, $(COCl)_2$, THF, −78 to −35 °C, 20 min; then Et_3N, −78 °C to room temp. (93%); v, α-diethoxyphosphonyl-γ-butyrolactone, LiCl, DMF, DIPEA (slow addition), 44 h (34% of **13**, 13% of **14**, 49% of **12**)

and reaction with enoate **6** at room temperature afforded compound **10** as the major product (60%) along with a small amount of the undesired isomer **11** (18%), arising from S_N2' attack of the alkoxide anion. Compound **10** was further elaborated to the aldehyde **12** by deprotection with HF–pyridine in acetonitrile and oxidation of the resultant primary alcohol with oxalyl dichloride-activated dimethyl sulfoxide (DMSO).[20] Wadsworth–Horner–Emmons olefination[21] of aldehyde **12** with α-(diethoxyphosphonyl)-γ-butyrolactone[22] in acetonitrile in the presence of LiCl, as described by Masamune and Roush,[23] occurred with only moderate selectivity for the

* The aldehyde **7** was prepared by ozonolysis of 3-*tert*-butyldimethylsilyloxypropene with reductive work-up (PPh_3) according to the method in ref. 19.

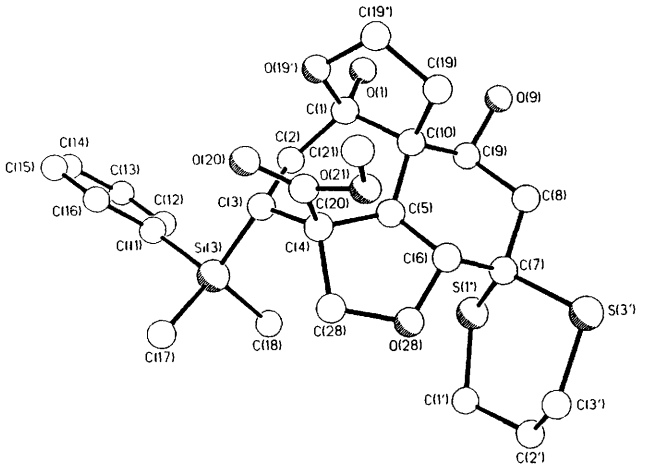
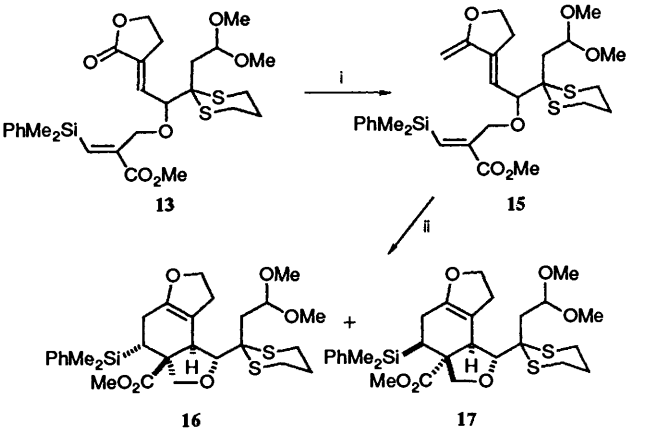


Fig. 1

required *E*-olefin **13**, the *E*:*Z* ratio being 3:2. A considerable increase in the *E*-selectivity was achieved by employing the more polar dimethylformamide (DMF) as solvent, albeit at the expense of a slower reaction rate. Typically, after 2 days the separable olefins **13** and **14** were obtained as a 2.7:1 mixture in excellent yield (>90%) with respect to consumed starting material, the conversion being 50%. We also investigated a very wide range of alternative conditions involving different solvents and bases, none of which improved the *E*/*Z* ratio. Alternative procedures such as a Peterson coupling[24] afforded the unwanted *Z* isomer only, in poor yield. Additionally, we briefly studied the interconversion of the *Z* isomer **14** into the required *E* isomer **13** using bases, irradiation with I_2 or diphenyl disulfide but without success. Nevertheless since isomers **13** and **14** were readily separated by flash chromatography we continued the synthesis.

Preparation of the triene **15** was achieved by methylenation of compound **13** by using 1.3 mole equivalents of the Tebbe reagent[25] in toluene–THF (2:1) at −50 to 35 °C as described by Evans[26] (Scheme 4). Under these conditions a high



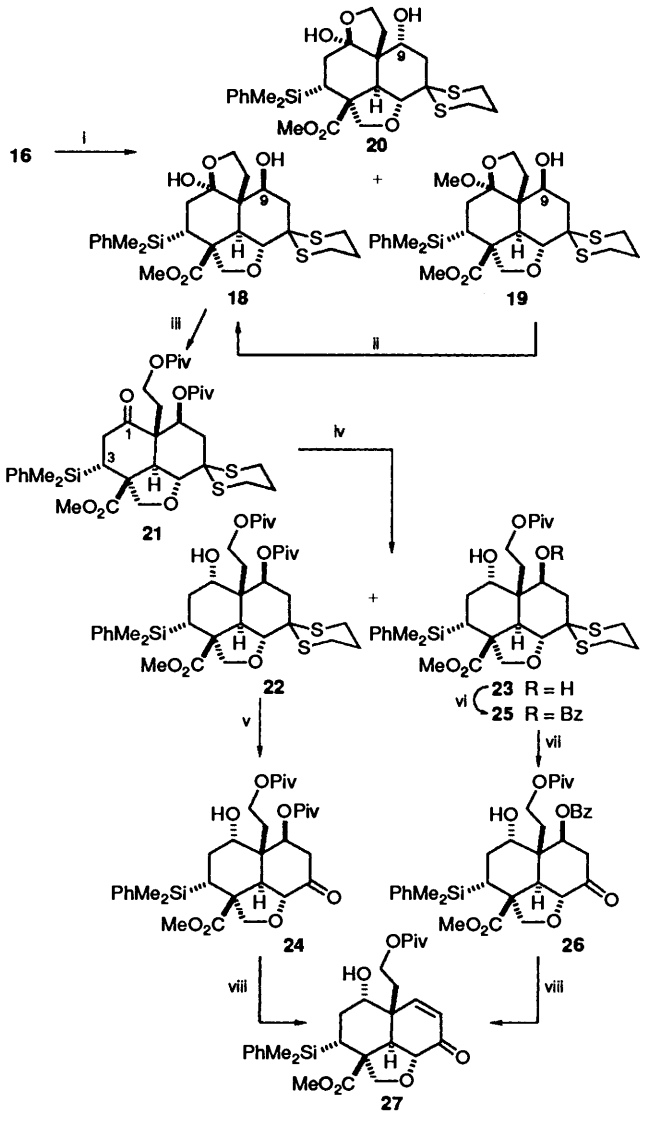
Scheme 4 *Reagents and conditions:* i, Tebbe reagent, cat. pyridine, toluene–THF, −50 to −35 °C, 140 min; ii, toluene, DIPEA, hydroquinone, 85 °C, 4 h (21% of **16**, 8% of **17**, 23% of **13**)

selectivity for the lactone carbonyl group was observed, although ~25% of the starting material **13** remained unchanged. The use of a larger excess of reagent caused a decrease in yield. Compound **15** was not purified but was used directly for the intramolecular Diels–Alder reaction to minimize decomposition of the dienol ether moiety. The cycloaddition was effected by warming of triene **15** at 85 °C in toluene, containing hydroquinone as an antioxidant and diisopropylethylamine (DIPEA) as a proton scavanger, to furnish the separate *trans*-fused *endo* product **16** and the *cis*-fused *exo* product **17** in a 5:2 ratio. Despite these precautions, the overall yield never exceeded 57% and more typically only 38–40% of the tricyclic products were obtained, with respect to consumed starting material **13**. Moreover, scale up of this reaction (beyond 5 g) caused a drop in yield and, consequently, we were forced to repeat the reactions many times to build up sufficient quantities of material.

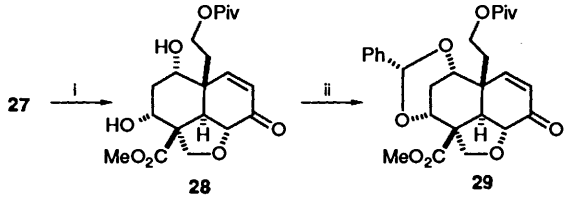
The stereochemical outcome of the Diels–Alder reaction was a very pleasing result for us since it very clearly demonstrated the *endo*-selectivity imparted by the sterically demanding silyl group, the absence of which leads to a 1:8 selectivity in favour of the *exo*-product.[15] Thus, the silicon had played an important role in promoting *endo*-selectivity and, as a consequence, had established four stereogenic centres with the correct relative configuration with respect to the natural product azadirachtin. The proof of the structure of these reactions follows from detailed NMR spectroscopic analysis and by X-ray crystal-structure determination of a later derivative. The next stage of the synthesis required stereoselective formation of the decalin ring system by an intramolecular aldol process using the electron-rich enol ether portion of compound **16** with a suitable electrophilic group generated from hydrolysis of the dimethyl acetal. Precedent for this process was established in our previous studies.[12] Indeed treatment of compound **16** with toluene-*p*-sulfonic acid (PTSA) in aq. acetonitrile at 55 °C for 5.5 h gave the cyclized products **18**, **19** and **20** in 45, 10 and 8% yield, respectively (Scheme 5). Other conditions for this cyclization were investigated but were generally less satisfactory. It should be noted that there is a preference for the formation of the C(9) β-products **18** and **19** and that the C(9) α-isomer **20** is formed as the minor component. We also established that compound **20** does not equilibrate and reverse under the reaction conditions. In other experiments not reported here[27] we have shown that the minor product **20** is a potentially useful synthetic intermediate although its further elaboration was not progressed at this stage. The methyl ketal **19** could be readily converted into the hemiketal **18** in reasonable yield by acid-catalysed hydrolysis in aq. acetonitrile. Single-crystal X-ray diffraction analysis of the crystalline decalin **18** enabled unequivocal stereochemical assignment and further confirmed the correctness of previous assignments (Fig. 1).

With good supplies of hemiketal **18** to hand the synthesis was continued by trapping of the hemiketal group in **18** in its open form by reaction with pivaloyl chloride in methylene dichloride containing pyridine and 4-(dimethylamino)pyridine (DMAP) as catalyst to obtain the cyclohexanone **21** in excellent yield. Other hindered trapping agents such as trityl chloride, *tert*-butyldiphenylsilyl chloride or triisopropylbenzenesulfonyl chloride were unsuccessful. Treatment of compound **21** with sodium borohydride in methanolic THF effected a highly stereoselective reduction of the C-1 carbonyl group, the nucleophile approaching exclusively *via* an equatorial trajectory from the β-face opposite to the C(3) dimethyl(phenyl)silyl group, to furnish the axial C(1) alcohols **22** and **23** in a 6:1 ratio. The latter compound resulted from saponification of the secondary pivalate ester under the reaction conditions. The excellent stereoselectivity is undoubtedly due to the controlling influence of the sterically demanding dimethyl(phenyl)silyl substituent, pronounced 1,3-diaxial interactions disfavouring axial approach of the reducing agent.

Thus, the silicon group has played a major role in establishing all the stereogenic centres in this substituted decalin intermediate. Hydrolysis of the 1,3-dithiane moiety of compound **22** with methyl iodide in aq. acetonitrile[28] afforded the ketone **24**. The minor product **23**, formed earlier, was also synthetically useful and, after benzoylation to compound **25** and similar



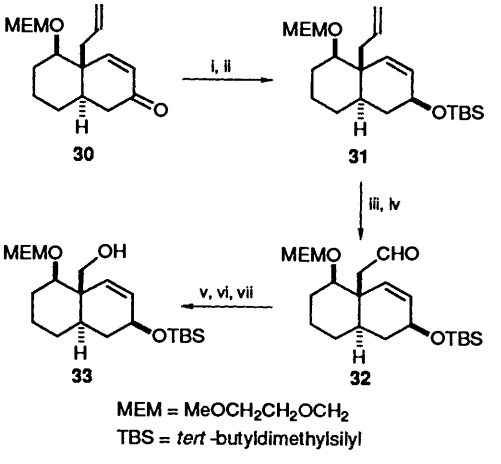
Scheme 5 *Reagents and conditions:* i, cat. PTSA, 0.5% water–MeCN, 55 °C, 5.5 h; then 6% water–MeCN, room temp., 2 h (45% of **18**, 10% of **19**, 8% of **20**); ii, cat., PTSA, 0.5 to 5.7% water–MeCN, 53 °C to room temp., 6.25 h (59%); iii, pivaloyl chloride, pyridine, DMAP, CH_2Cl_2, 45 °C, 72 h (81%); iv, $NaBH_4$, MeOH–THF, room temp., 90 min (82% of **22**, 14% of **23**); v, MeI, $CaCO_3$, water–MeCN, 55 °C, 7 h (98%); vi, benzoyl cyanide, Et_3N, CH_2Cl_2–MeCN, 0 °C, 45 min (79%); vii, MeI, $CaCO_3$, water–MeCN, 55 °C, 7 h (100%); viii, DBU, CH_2Cl_2, room temp., 135 min (100%)



Scheme 6 *Reagents and conditions:* i, $Hg(O_2CCF_3)_2$, AcOH–TFA, room temp., 10 min; then AcOOH, 10 °C to room temp., 2 h (85%); ii, PhCHO, PTPS, C_6H_6, reflux, 24.5 (83% of **29**, 12% of **28**)

removal of the dithiane group, gave compound **26**. The leaving groups in compounds **24** and **26** at the C(9) position facilitated β-elimination to give the same enone **27** in quantitative yield on treatment with 1,8-diazabicylo[5.4.0]undec-7-ene (DBU) in CH_2Cl_2 at room temperature. Preparation of the 1,3-diaxial diol **28** by silyl-Baeyer–Villiger oxidation of compound **27** required modification of the Fleming conditions[14] owing to the low reactivity of the sterically encumbered silane (Scheme 6). The phenyltrialkylsilane was premixed with acetic acid and trifluoroacetic acid (TFA) containing mercury(II) trifluoroacetate at room temperature to cause rapid displacement of the phenyl group by mercuridesilylation.[29] In contrast, mercuridesilylation with mercury(II) acetate in acetic acid[14,29] proved rather sluggish. After 10 min the mixture was cooled to 10 °C and peracetic acid was added to effect oxidative carbon–silicon bond cleavage with retention of configuration. In this way an 85% yield of the diol **28** could be realized. The reaction was reproducible and better than any alternative sequences which we investigated, where problems were encountered originating in the low reactivity of the sterically encumbered dimethyl(phenyl)silyl group. The silicon group has consequently played a dominant role in the synthesis of this polyoxygenated decalin intermediate. The 1,3-diol in **28** could be protected as the corresponding benzylidene acetal **29** by reaction with benzaldehyde in the presence of pyridinium tosate (PTPS) and azeotropic removal of water.

Before committing valuable material for the last steps of the synthesis, we undertook a model study to investigate the introduction of the final tetrahydrofuran hemiacetal unit. This was considered necessary since we intended to use a new ring-contraction approach to this group. Consequently, we synthesized* the model decalin **30** containing an acid-sensitive group [(methoxyethoxy)methoxy, OMEM], a side-chain suitable for degradation and an enone which corresponds to the real system **29**. Stereoselective reduction of compound **30** with sodium borohydride and cerium(III) chloride,[30] followed by silylation with *tert*-butyldimethylsilyl chloride gave compound **31** as expected (Scheme 7). Chemoselective cleavage of the



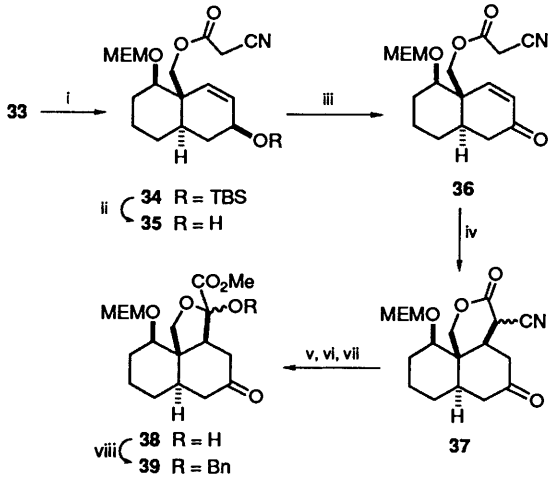
Scheme 7 *Reagents and conditions:* i, $NaBH_4$, $CeCl_3·7H_2O$, MeOH, 0 °C, 30 min (82%); ii, Bu^tMe_2SiCl, imidazole, DMF, room temp., 45 min (91%); iii, cat. OsO_4, *N*-methylmorpholine *N*-oxide, Bu^tOH–THF–water, 2 h; iv, $NaIO_4$, MeOH–water, room temp., 5 min (79% over 2 steps); v, lithium diisopropylamide (LDA, *in situ*), THF, −78 °C, 30 min; then 1,3-dimethyl-3,4,5,6-tetrahydro-2(1*H*)-pyrimidone, *tert*-butyldimethylsilyl chloride, −78 °C to room temp., 2 h; vi, O_3/O_2, Sudan Red 7B, CH_2Cl_2, −78 °C, 6.5 h; then PPh_3, −78 °C to room temp., 12 h; vii, $NaBH_4$, MeOH, room temp., 20 min (41% over 3 steps)

terminal double bond in compound **31** was achieved in two steps by *cis*-hydroxylation with catalytic amounts of OsO_4 using *N*-methylmorpholine *N*-oxide as co-oxidant,[31] followed

* The model compound **30** was prepared by Robinson annulation of 2-(prop-2-enyl)cyclohexane-1,3-dione and methyl vinyl ketone, followed by chemoselective reduction of the ketone, protection of the resultant alcohol with (2-methoxyethoxy)methyl chloride, and enone double-bond transposition; see ref. 27.

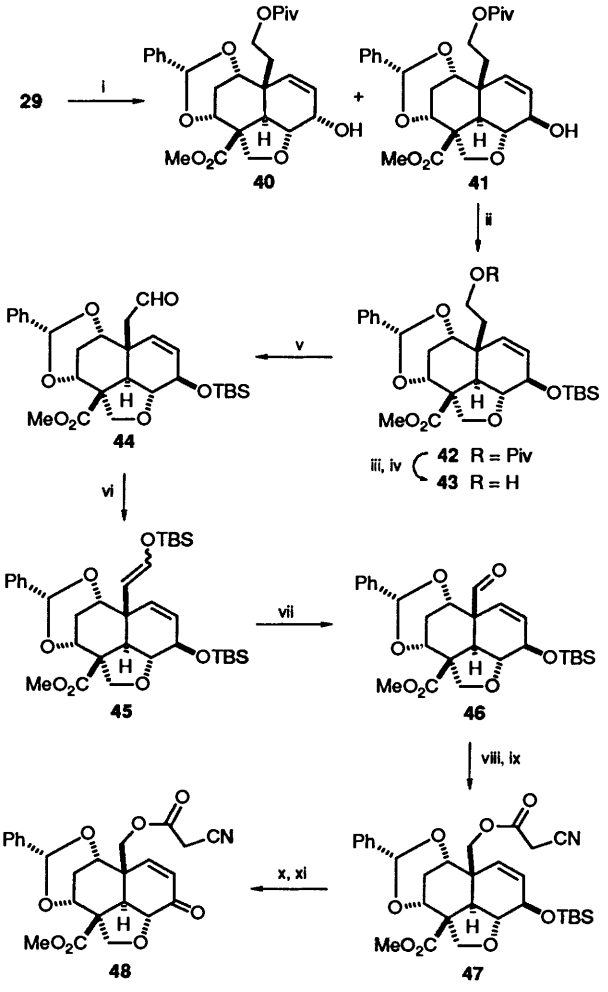
by diol cleavage with sodium periodate to obtain the aldehyde **32** in good overall yield. The aldehyde was transformed into the alcohol **33** in a sequence of reactions involving generation of its silyl enol ether by quenching of its lithium enolate with *tert*-butyldimethylsilyl chloride and subsequent chemoselective ozonolysis of the electron-rich enol double bond using Sudan Red 7B dye as an indicator.[32] On work-up with triphenylphosphine the crude aldehyde intermediate was reduced with sodium borohydride in methanol to give the alcohol **33**.

We considered various strategies to construct the required tetrahydrofuran hemiketal unit starting from compound **33**. However, we were attracted to a new approach, in which we envisioned the initial annulation of a six-membered ring by an intramolecular conjugate addition of an α-ketoacetyl anion-equivalent to an octalone intermediate. This analysis suggested the α-cyanoacetyl group as the required anion equivalent, since its α-hydroxylation would release a keto group, leading to an α-keto-δ-lactone, *via* initial formation of the corresponding α-cyanohydrin. We anticipated that this reactive α-keto lactone species would undergo ring opening upon methanolysis, followed by re-closure of the resultant hydroxy α-keto ester to the desired cyclic hemiketal. Indeed, treatment of compund **33** with cyanoacetic acid, toluene-*p*-sulfonyl chloride and pyridine[33] in CH_2Cl_2 gave the cyanoacetate **34** in 94% yield (Scheme 8). After deprotection of the silyl ether **34**, the resulting alcohol **35** was oxidized with pyridinium dichromate (PDC)[35] and the crude enone **36** was immediately subjected to cyclization mediated by DBU to give the α-cyano lactones **37** in a 6.7:1 ratio in excellent yield. The stage was now set for an investigation of the key reaction which required some experimentation until we found that hydroxylation of lactone **37** was best achieved with *m*-chloroperbenzoic acid (MCPBA) in a biphasic CH_2Cl_2–pH 8 buffer system. Subsequent reaction of the crude intermediate with anhydrous methanol in the presence of triethylamine at room temperature furnished the tetrahydrofuran hemiketal **38** in 59% yield as a 8:1 mixture at the anomeric position in favour of the required epimer corresponding to the natural product. Finally, hemiketal **38** was benzylated with benzyl bromide and silver(I) oxide to give the protected derivative **39** (Scheme 8).



Scheme 8 *Reagents and conditions:* i, Cyanoacetic acid, toluene-*p*-sulfonyl chloride, pyridine, CH_2Cl_2, room temp., 20 min (94%); ii, HF–pyridine, MeCN, 27 °C, 26 h (98%); iii, PDC, 4 Å sieves, CH_2Cl_2, room temp., 2 h; iv, DBU, CH_2Cl_2, room temp., 4 h (91% over 2 steps); v, MCPBA, CH_2Cl_2–pH 8 buffer, 0 °C, 2.5 h; vi, MeOH, Et_3N, room temp., 4.5 h; vii, CH_2N_2, CH_2Cl_2, room temp. (59% over 3 steps); viii, BnBr, Ag_2O, DMF, room temp., 6 h (72%)

Following the completion of this successful study we were able to proceed confidently with the real system and have achieved the synthesis of a potential decalin coupling fragment of azadirachtin both in its racemic and enantiomerically pure forms. Initially we found that upon reduction of enone **29** with sodium borohydride and cerium(III) chloride a 1:1 mixture of the C(7) epimeric alcohols **40** and **41** was produced (Scheme 9).



Scheme 9 *Reagents and conditions:* i, $NaBH_4$, $CeCl_3 \cdot 7H_2O$, MeOH, 0 °C, 10 min (44% of **40**, 53% of **41**); ii, *tert*-butyldimethylsilyl chloride, imidazole, DMF, 35 °C, 2 h (97%); iii, LiOH·H_2O, aq. EtOH, 60 °C, 5 h; iv, CH_2N_2, CH_2Cl_2, room temp. (66% over 2 steps); v, Dess–Martin periodinane, pyridine, CH_2Cl_2, room temp., 40 min (91%); vi, $CF_3CO_2SiMe_2Bu^t$, Et_3N, CH_2Cl_2, −15 °C, 135 min (75% of **45**, 21% of **44**); vii, O_3/O_2, Sudan Red 7B, CH_2Cl_2, −78 °C, 50 min; then PPh_3, −78 °C to room temp., 12 h (82%); viii, $Zn(BH_4)_2$, Et_2–THF, −10 to −5 °C, 165 min; ix, cyanoacetic acid, toluene-*p*-sulfonyl chloride, pyridine, CH_2Cl_2, 15 °C, 15 min (93% over 2 steps); x, TBAF, 4 Å sieves, THF, room temp., 15 min (94%); xi, PDC, 4 Å sieves, CH_2Cl_2, room temp., 1.5 h (89%)

Both these compounds can be transformed into the final target molecules. However, for this paper we have restricted our experimental procedures to report the conversion of the β-isomer **41** in the racemic series while the α-isomer **40** was processed *via* optical resolution to the enantiomerically pure final products. Compound **40** is formed as the only stereoisomer on reduction of enone **29** with lithium tri-*sec*-butylborohydride. This reaction would now be the preferred pathway by which enone **29** would be transformed into the final compounds.

After protection of enol **41** as its *tert*-butyldimethylsilyl ether **42**, the side chain was degraded in the following sequence of reactions involving hydrolysis of the pivaloyl group with lithium hydroxide to afford compound **43** which, on oxidation

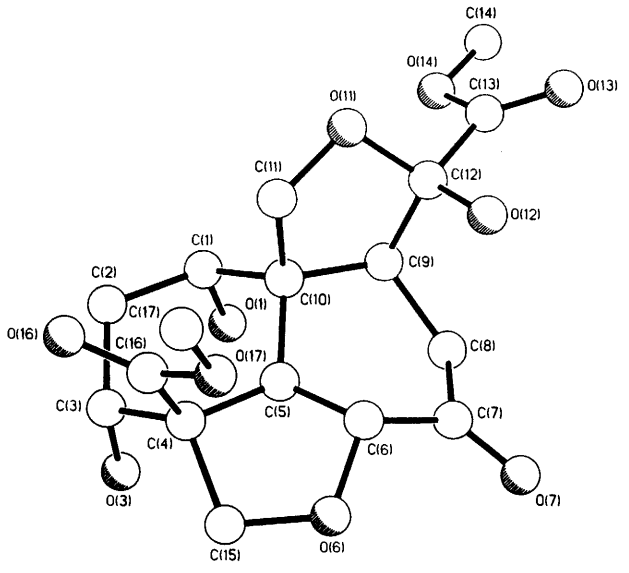
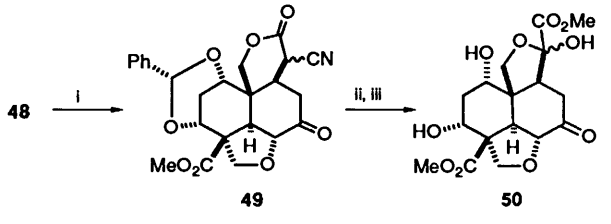


Fig. 2

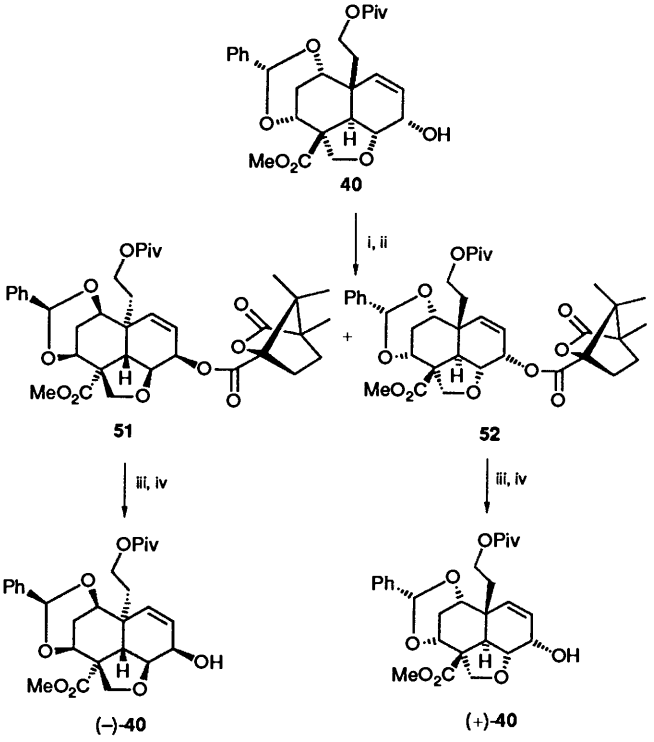
with the Dess–Martin periodinane reagent,[35] gave the aldehyde **44** (Scheme 9). Compound **44** was converted into the corresponding enol ether **45** by treatment with *tert*-butyldimethylsilyl triflate, and the product was selectively ozonized to the aldehyde **46** in analogy to the model studies. This intermediate was reduced with zinc borohydride and the intermediate alcohol was immediately allowed to react with cyanoacetic acid in the presence of toluene-*p*-sulfonyl chloride and pyridine to give the cyanoacetate **47**, also following precedent from the model work. The silicon protecting group in enone was removed by using tetrabutylammonium fluoride (TBAF) in the presence of activated 4 Å molecular sieves as desiccant.[36,*] Oxidation of the resultant allylic alcohol with PDC gave the corresponding enone **48** in excellent yield. Pleasingly, all reactions in these final stages of the synthesis proceeded extremely well.

Cyclization of cyanoacetate **48** was best achieved with lithium hexamethyldisilazide (LHMDS) to give a diastereoisomeric mixture of α-cyano lactones **49** in quantitative yield (Scheme 10). Lastly we found that α-hydroxylation of cyano lactone **49**



Scheme 10 *Reagents and conditions:* i, LHMDS, THF, 0 °C to room temp., 70 min (100%); ii, dimethyldioxirane, acetone, 0 °C, 22 min, iii, PTPS, MeOH, 5.5 h (70% over 2 steps)

with dimethyldioxirane[38] and treatment of the crude α-cyanohydrin intermediate with methanol and PTPS provided the decalin fragment **50** as a 4.4:1 mixture† of hemiketal



Scheme 11 *Reagents and conditions:* i, (1*S*,4*R*)-(−)-Camphanic acid chloride, pyridine, DMAP, CH_2Cl_2, room temp., 21 h; ii, separation by preparative HPLC (43% of **51** and 44% of **52**); iii, K_2CO_3, MeOH, room temp., 11 h; iv, pivaloyl chloride, pyridine, 45 min [95% of (+)-**40** and 90% of (−)-**40** over 2 steps]

epimers in favour of the desired isomer with respect to the natural product.

This fragment now contains all of the functional groups necessary for further elaboration to azadirachtin **1**. Confirmation of the structure of compound **50** was achieved by highfield ^1H and ^{13}C NMR spectroscopy and single-crystal X-ray diffraction analysis (Fig. 2). This result also provides support for previous stereochemical assignments at the earlier stages of the synthesis.

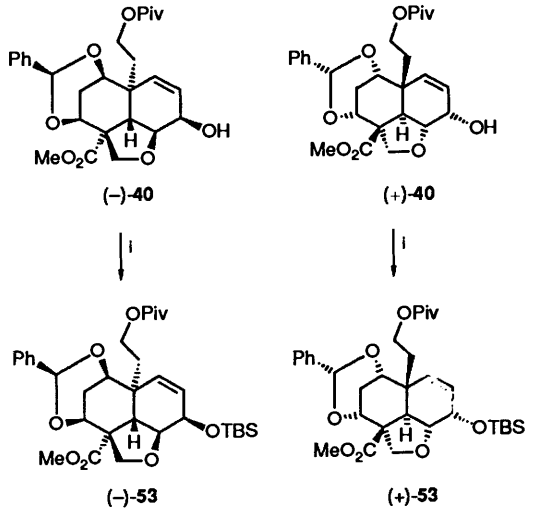
In a similar series of reactions the α-alcohol **40** was converted into the same decalin fragment, although through the resolution sequence outlined in Scheme 11, this was obtained in its optically pure arrangement. Thus acylation of compound **40** with (1*S*,4*R*)-(−)-camphanic acid chloride gave the easily separated diastereoisomers **51** and **52**.

Methanolysis of the diastereoisomeric camphanates **51** and **52** was accompanied by partial saponification of the pivalate ester, and treatment of the crude product mixture with pivaloyl chloride and pyridine afforded the enantiomerically pure alcohols (+)-**40** and (−)-**40**, respectively, in excellent overall yields. The resolved allylic alcohols were protected as their *tert*-butyldimethylsilyl ethers. Compound (+)-**53** proved to be crystalline, allowing determination of its absolute configuration as shown (Fig. 3) (Scheme 12).

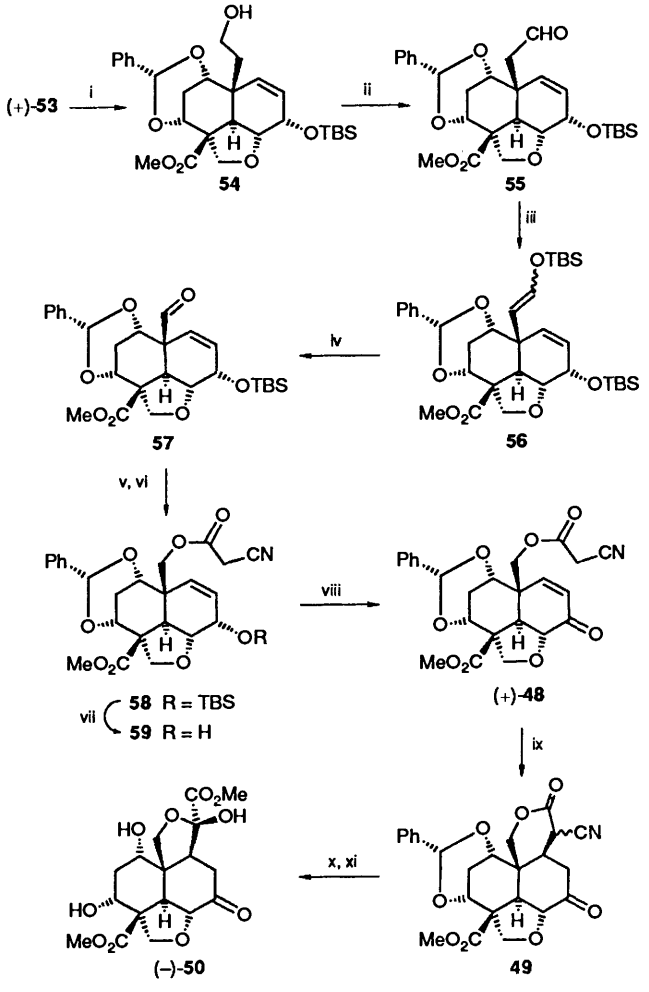
The allylic ether (+)-**53**, having the correct absolute configuration, was saponified with lithium hydroxide to afford the alcohol **54** (Scheme 13). Oxidation of compound **54**, as before, with periodinane gave the aldehyde **55**. Degradation of the side chain by ozonolysis of the intermediate silyl enol ether **56** afforded the aldehyde **57**, following the related reactions in the epimeric series discussed earlier. Reduction of aldehyde **57** with zinc borohydride and coupling of the alcohol product with cyanoacetic acid gave ester **58**. Removal of the silyl protection from compound **58** produced the allylic alcohol **59** which on oxidation with PDC, generated the enone (+)-**48** in optically

* Shirahama and co-workers have observed a considerable increase in reaction rate and yield of the cleavage of 2-(trimethylsilyl)ethoxymethyl ethers with TBAF by adsorbing water in the reaction mixture with activated 4 Å molecular sieves, see ref. 37.

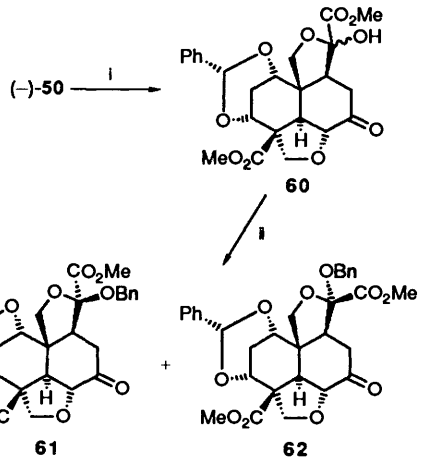
† The diastereoisomeric ratio at C(11) varied between 4.4:1 and 7:1 in favour of the isomer having the natural configuration depending on the reaction time.



Scheme 12 *Reagents and conditions:* i, $CF_3SO_2SiMe_2Bu^t$, 2,6-lutidine, CH_2Cl_2, 0 °C, 25 min (96%)



Scheme 13 *Reagents and conditions:* i, $LiOH{\cdot}H_2O$, aq. EtOH, 60 °C, 5 h; then CH_2N_2, CH_2Cl_2, room temp. (91% over 2 steps); ii, Dess–Martin periodinane, pyridine, CH_2Cl_2, 13 °C to room temp., 25 min (90%); iii, $CF_3SO_2SiMe_2Bu^t$, Et_3N, CH_2Cl_2, −15 to −5 °C, 2.5 h, recovered **55** (52%) was recycled once; iv, O_3/O_2, Sudan Red 7B, CH_2Cl_2, −78 °C, 1 h, then PPh_3, −78 °C to room temp., 12 h (85% over 2 steps); v, $Zn(BH_4)_2$, Et_2O–THF, −10 °C, 3 h; vi, cyanoacetic acid, toluene-*p*-sulfonyl chloride, pyridine, CH_2Cl_2, room temp., 20 min (98% over 2 steps); vii, TBAF, 4 Å sieves, THF, room temp., 4 h (93% of **59**, 4% of **58**); viii, PDC, 4 Å sieves, CH_2Cl_2, room temp., 2.75 h (88%); ix, LHMDS, THF, 0 °C to room temp., 70 min (100%); x, dimethyldioxirane, acetone, 0 °C, 22 min; xi, PPTS, MeOH, 5.5 h (70% over 2 steps)



Scheme 14 *Reagents and conditions:* i, PhCHO, PTPS, C_6H_6, reflux, 4.6 h (74%); ii, BnBr, Ag_2O, DMF, room temp., 3.5 h (61% of **61**, 19% of **62**)

pure form. As in the racemic synthesis this intermediate was transformed into the α-cyano lactone **49** and into the final material (−)-**50** by use of the same reagent combination.

The preparation of the potential coupling fragment **61** for use in the total synthesis of azadirachtin was achieved *via* initial protection of the 1,3-diaxial diol moiety in (−)-**50** as the benzylidene acetal **60** by treatment with benzaldehyde and PTPS as catalyst (Scheme 14). The remaining hemiketal hydroxy group was benzylated by using benzyl bromide and silver(I) oxide to obtain the fully protected system **61** as the major product, along with small amounts of the C(11) epimer **62**.

Obviously the C(7) carbonyl group in compound **61** is now ideally positioned to facilitate the introduction of all the remaining substituents and provides coupling opportunities for the total synthesis of azadirachtin.

In summary, we have devised a synthetic strategy to appropriately substituted decalins suitable for the total synthesis of the insect antifeedant azadirachtin. In this work the dimethyl(phenyl)silyl group played a key role in controlling the stereochemistry of several reactions. Furthermore, a new procedure for the formation of the required tetrahydrofuran hemiketal portion of these important molecules has been established.

Experimental

General.—^1H NMR spectra were recorded in $CDCl_3$ unless otherwise stated, at 90, 270 or 500 MHz on spectrometers JEOL FX 90Q, JEOL GFX 270 or Bruker AM 500, respectively. Residual protic solvent, *i.e.* $CHCl_3$ (δ_H 7.26) or C_6D_5H (δ_H 7.20), was used as internal reference. *J*-Values were measured in Hz. ^{13}C NMR spectra were recorded in $CDCl_3$ unless otherwise stated, at 125.8 MHz on a Bruker AM 500 NMR spectrometer and using the resonances of $CDCl_3$ (δ_C 77.0, t) or C_6D_6 (δ_C 128.0, t) as internal reference. IR spectra were recorded on a Perkin-Elmer 983G spectrometer. Mass spectra were recorded under EI conditions, unless otherwise stated, on VG-7070B, VG 12-253, Autospec Q and VG ZAB-E instruments. Microanalyses were performed in the Imperial College Chemistry Department microanalytical laboratory and by MEDAC Ltd. at the Department of Chemistry, Brunel University. M.p.s were determined on a Reichert hot-stage apparatus and are uncorrected. Optical rotations were measured with an Optical Activity AA-1000 polarimeter with acid- and ethanol-free $CHCl_3$ as solvent unless otherwise stated. $[\alpha]_D$-Values are given in units of 10^{-1} deg cm^2 g^{-1}. Molecular modelling was

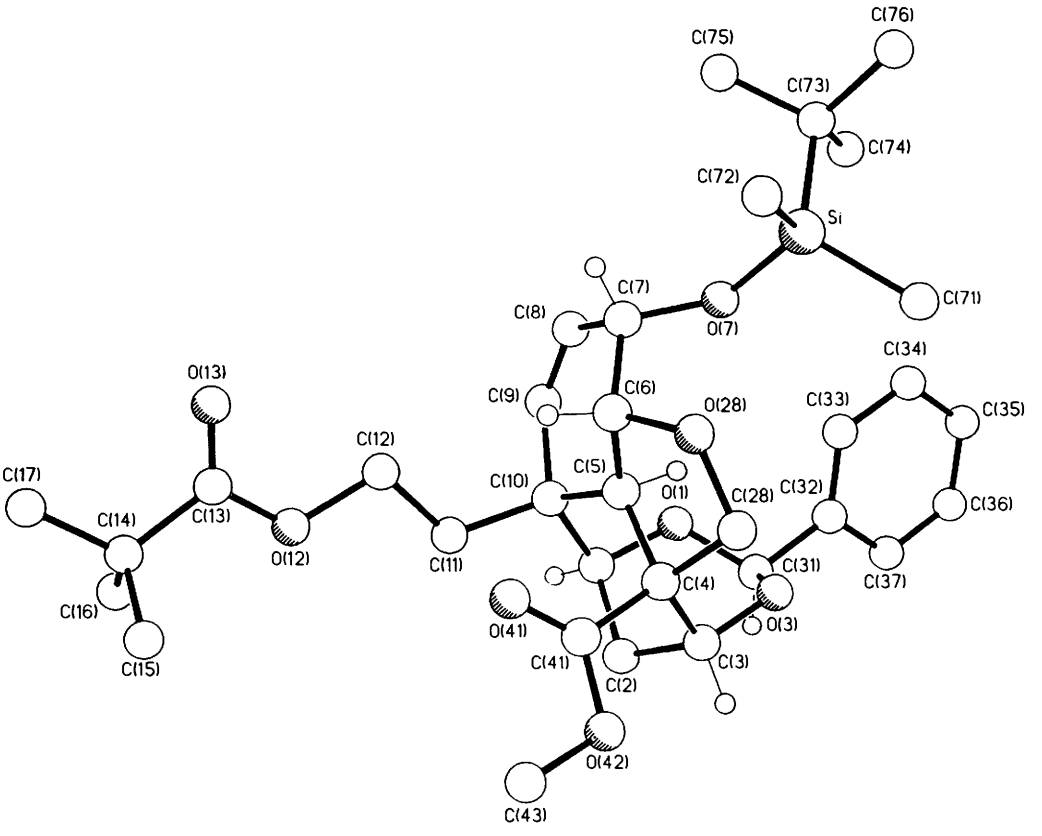


Fig. 3

performed using the MACROMODEL package† and the MOPAC program,[39] on an Evans and Sutherland PS-390 graphics terminal and Tektronic Cache system, respectively. Flash column chromatography was performed on Merck Kieselgel 60 (230–400 mesh) unless otherwise stated. Preparative HPLC was performed on a Dynamax Macro Si column. Florisil refers to 230–300 US mesh Florisil as supplied by BDH Ltd. Diethyl ether and THF were distilled from sodium–benzophenone ketyl; methylene dichloride from phosphorus pentaoxide; toluene from sodium; acetonitrile from calcium hydride; and methanol from magnesium. Light petroleum refers to the fraction boiling in the range 40–60 °C and which was distilled prior to use, as was ethyl acetate. Other solvents and reagents were purified by standard procedures as necessary. Analytical TLC was performed using pre-coated glass-backed plates (Merck Kieselgel $60F_{254}$) and compounds were visualized by acidic ammonium molybdate(IV) or iodine as appropriate.

Crystal Data for (2aR*,3R*,4aR*,7aS*,8S*,10aR*,10bR*)-*Methyl* 3-*Dimethyl(phenyl)silyl*-4a,8-*dihydroxyperhydronaphtho*[1,8-bc:5,4a-b′]*difuran*-10-*spiro*-2′-(1′,3′-*dithiane*)-2a-*carboxylate* **18**.—Single crystals of compound **18** were grown at room temperature from methanol. $C_{26}H_{36}O_6S_2Si$, M = 536.8, triclinic, a = 11.437(4), b = 12.616(5), c = 20.018(7) Å, α = 72.24(3), β = 81.55(3), γ = 80.76(3)°, V = 2700 Å^3, space group $P\bar{1}$, Z = 4 (2 crystallographically independent molecules), D_c = 1.32 g cm^{-3}, Cu radiation, λ = 1.541 78 Å, μ(Cu-Kα) = 25 cm^{-1}, F(000) = 1144. Data were measured on a Nicolet R3m diffractometer with Cu-Kα radiation (graphite monochromator) using ω scans. A crystal of dimensions 0.07 × 0.27 × 0.57 mm was used. 7294 Independent reflections ($2\theta \leqslant 116°$) were measured, of which 6368 had $|F_o| > 3\sigma(|F_o|)$, and were considered to be observed. The data were corrected for Lorentz and polarization factors; no absorption correction was applied. The structure was solved by direct methods. The non-hydrogen atoms were refined anisotropically. The hydroxy protons on O(1), O(9), O(51) and O(59) were located from a ΔF map and were refined isotropically. The positions of the remaining hydrogen atoms were idealized, C–H = 0.96 Å, assigned isotropic thermal parameters, U(H) = 1.2 U_{eq}(C), and allowed to ride on their parent carbon atoms. The methyl groups were refined as rigid bodies. Refinement was by block-cascade full-matrix least-squares to R = 0.053, R_w = 0.059 [$w^{-1} = \sigma^2(F) + 0.001\,62\,F^2$]. The maximum and minimum residual electron densities in the final ΔF map were 0.55 and −0.38 e Å^{-3}, respectively. The mean and maximum shift/error in the final refinement were 0.024 and 0.116, respectively. Computations were carried out on an Eclipse S140 computer using the SHELXTL program system.[40] Atomic coordinates and selected bond lengths and angles are given in Tables 1 and 2.‡

Crystal Data for (2aR*,4aS*,5S*,7aS*,8S*,10R*,10aS*,-10bR*)-*Dimethyl* 5,8,10-*Trihydroxy*-3-*oxoperhydronaphtho*-[1,8-bc:4,4a-c′]*difuran*-5,10a-*dicarboxylate* **50**.—Single crystals of the racemic compound **50** were grown at room temperature from ethyl acetate–methanol. $C_{17}H_{22}O_{10}$, M = 386.4, triclinic, a = 7.654(1), b = 9.502(2), c = 12.479(4) Å, α = 110.65(2), β = 94.19(2), γ = 97.53(2)°, V = 835 Å^3, space group $P\bar{1}$, Z = 2, D_c = 1.54 g cm^{-3}, Mo radiation, λ = 0.710 73 Å, μ(Mo-Kα) = 1 cm^{-1}, F(000) = 408. Data were measured on a Siemens

† MACROMODEL, the Batchmin program and the associated documentation are available from W. C. Still, Columbia University, New York.

‡ *Supplementary data* (see section 5.6.3 of Instructions for Authors, January issue). Other crystallographic material (hydrogen coordinates, thermal parameters) have been deposited at the Cambridge Crystallographic Data Centre.

Table 1 Atom co-ordinates ($\times 10^4$) with estimated standard deviations in parentheses for compound **18**

Atom	*x*	*y*	*z*
O(1)	1 296(2)	962(1)	−410(1)
C(1)	1 277(3)	537(2)	332(2)
C(2)	1 866(3)	−673(2)	546(2)
C(3)	1 830(3)	−1 257(2)	1 353(2)
C(4)	1 902(2)	−398(2)	1 765(1)
C(5)	2 455(2)	602(2)	1 235(1)
C(6)	2 977(3)	1 187(2)	1 645(1)
C(7)	3 988(3)	1 813(3)	1 167(2)
C(8)	3 414(3)	2 577(3)	506(2)
C(9)	2 803(3)	1 971(3)	117(2)
O(9)	2 382(2)	2 825(2)	−482(1)
C(10)	1 809(3)	1 343(2)	612(2)
C(11)	2 429(3)	−3 421(3)	986(2)
C(12)	3 055(4)	−3 541(3)	360(2)
C(13)	2 653(4)	−4 135(4)	−23(3)
C(14)	1 658(5)	−4 618(3)	200(3)
C(15)	996(5)	−4 502(4)	803(3)
C(16)	1 379(4)	−3 903(4)	1 190(3)
C(17)	2 758(4)	−3 435(3)	2 462(2)
C(18)	4 472(3)	−2 324(3)	1 212(2)
Si(3)	2 907(1)	−2 595(1)	1 515(1)
C(19)	717(3)	2 159(3)	769(2)
C(19′)	−356(3)	1 655(3)	693(2)
O(19′)	75(2)	539(2)	653(1)
C(20)	682(3)	−143(3)	2 148(2)
O(20)	−117(2)	−694(2)	2 276(2)
O(21)	612(2)	772(2)	2 361(1)
C(21)	−505(3)	1 074(4)	2 745(2)
C(28)	2 825(3)	−688(3)	2 311(2)
O(28)	3 349(2)	306(2)	2 253(1)
S(1′)	5 233(1)	922(1)	854(1)
C(1′)	6 068(3)	279(4)	1 608(2)
C(2′)	6 437(3)	1 093(4)	1 933(2)
C(3′)	5 377(3)	1 769(3)	2 234(2)
S(3′)	4 513(1)	2 753(1)	1 563(1)
O(51)	6 270(2)	4 165(2)	5 491(1)
C(51)	6 614(3)	4 285(2)	4 765(2)
C(52)	7 000(3)	5 435(2)	4 378(1)
C(53)	7 307(3)	5 672(2)	3 567(1)
C(54)	7 951(3)	4 492(2)	3 373(1)
C(55)	8 402(2)	3 757(2)	4 041(1)
C(56)	9 326(3)	2 916(2)	3 816(1)
C(57)	10 196(3)	2 422(2)	4 379(2)
C(58)	9 418(3)	2 004(3)	5 086(2)
C(59)	8 403(3)	2 850(2)	5 278(1)
O(59)	7 833(2)	2 270(2)	5 945(1)
C(60)	7 556(3)	3 289(2)	4 692(1)
C(61)	6 918(3)	8 104(2)	3 525(2)
C(62)	7 263(4)	8 714(3)	3 919(2)
C(63)	6 469(4)	9 484(3)	4 169(2)
C(64)	5 303(4)	9 671(3)	4 036(2)
C(65)	4 925(3)	9 078(3)	3 652(2)
C(66)	5 724(3)	8 301(3)	3 407(2)
C(67)	8 094(3)	7 436(3)	2 209(2)
C(68)	9 461(3)	6 918(3)	3 517(2)
Si(53)	7 994(1)	7 029(1)	3 191(1)
C(69)	6 803(3)	2 393(3)	4 664(2)
C(69′)	5 551(3)	2 988(3)	4 576(2)
O(69′)	5 636(2)	4 172(2)	4 433(1)
C(70)	7 199(3)	4 150(3)	2 974(2)
O(70)	7 093(2)	3 196(2)	3 050(1)
O(71)	6 742(3)	4 989(2)	2 460(2)
C(71)	6 177(7)	4 678(4)	1 958(3)
C(78)	9 184(3)	4 640(3)	2 922(2)
O(78)	9 832(2)	3 524(2)	3 131(1)
S(51′)	11 075(1)	3 441(1)	4 481(1)
C(51′)	12 206(3)	3 614(3)	3 730(2)
C(52′)	12 929(3)	2 534(4)	3 652(2)
C(53′)	12 187(3)	1 749(3)	3 514(2)
S(53′)	11 150(1)	1 168(1)	4 260(1)

P4/PC diffractometer with Mo-Kα radiation (graphite monochromator) using ω scans. A crystal of dimensions 0.10 × 0.17 × 0.50 mm was used. 2938 Independent reflections ($2\theta \leqslant 50°$) were measured, of which 2420 had $|F_o| > 3\sigma(|F_o|)$, and were considered to be observed. The data were corrected for Lorentz and polarization factors; no absorption correction was applied. The structure was solved by direct methods. The non-hydrogen atoms were refined anisotropically. The bridgehead and hydroxy protons were located from a ΔF map and were refined isotropically. The positions of the remaining hydrogen atoms were idealized, C–H = 0.96 Å, assigned isotropic thermal parameters, $U(H) = 1.2\ U_{eq}(C)$, and allowed to ride on their parent carbon atoms. The methyl groups were refined as rigid bodies. Refinement was by block-cascade full-matrix least-squares to $R = 0.043$, $R_w = 0.045$ [$w^{-1} = \sigma^2(F) + 0.000\ 20\ F^2$]. The maximum and minimum residual electron densities in the final ΔF map were 0.27 and −0.19 e Å^{-3}, respectively. The mean and maximum shift/error in the final refinement were 0.000 and 0.000, respectively. Computations were carried out on an IB model 70 386 PC using the SHELXTL program system.[40] Atomic co-ordinates and selected bond lengths and angles are given in Tables 3 and 4.*

Crystal Data for (2aS,3R,5S,5aR,8S,8aR,8bR)-*Methyl* 3,5-[(R)-*Benzylidenedioxy*]-8-tert-*butyldimethylsiloxy*-5a-(2-*pivaloyloxyethyl*)-4,5,5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]-*furan*-2a-*carboxylate* (+)-**53**.—Crystals of compound (+)-**53** were grown at room temperature from diethyl ether–light petroleum. $C_{33}H_{48}O_8Si$, M = 600.8, orthorhombic, a = 10.698(1), b = 12.139(1), c = 26.157(3) Å, V = 3397 Å^3, space group $P2_12_12_1$, $Z = 4$, $D_c = 1.17$ g cm^{-3}, Cu radiation, λ = 1.541 78 Å, μ(Cu-Kα) = 10 cm^{-1}, $F(000) = 1296$. Data were measured on a Siemens R3/PC diffractometer wih Cu-Kα radiation (graphite monochromator) using ω scans. A crystal of dimensions 0.20 × 0.27 × 0.50 mm was used. 5414 Independent reflections ($2\theta \leqslant 116°$) were measured, of which 3532 had $|F_o| > 4\sigma(|F_o|)$, and were considered to be observed. The data were corrected for Lorentz and polarization factors; no absorption correction was applied. The structure was solved by direct methods. The non-hydrogen atoms were refined anisotropically. A ΔF map revealed the presence of disorder in one of the *tert*-butyl groups. Two 50% orientations were identified and each was refined subject to C–C distance constraint. The positions of the hydrogen atoms were idealized, C–H = 0.96 Å, assigned isotropic thermal parameters, $U(H) = 1.2\ U_{eq}(C)$, and were allowed to ride on their parent carbon atoms. The methyl groups were refined as rigid bodies. The absolute configuration of the molecule was determined by an R-factor test, ($R^+ = 0.0595$, $R^- = 0.0621$), by the measurement of a full set of Bijvoet pairs and by the refinement of a free variable η which multiplies all f'' [this parameter refined to a value of 1.09 (12)]. Refinement was by block-cascade full-matrix least-squares to $R = 0.060$, $R_w = 0.063$ [$w^{-1} = \sigma^2(F) + 0.000\ 70\ F^2$]. The maximum and minimum residual electron densities in the final ΔF map were 0.37 and −0.26 e Å^{-3}, respectively. The mean and maximum shift/error in the final refinement were 0.043 and 0.285, respectively. Computations were carried out on an IBM model 70386 PC using the SHELXTL program system.[40] Atomic co-ordinates and selected bond lengths and angles are given in Tables 5 and 6.*

(Z)-*Methyl* 2-*Diethoxymethyl*-3-*dimethyl*(*phenyl*)*silylprop*-2-*enoate* **3**.—Dimethyl(phenyl)silyllithium (107 cm^3 of a 1 mol dm^{-3} solution in THF,[16] 107 mmol) was added slowly during 25 min to a stirred suspension of copper(I) cyanide (4.79 g, 53.5

* *Supplementary data* (see section 5.6.3 of Instructions to Authors, January issue). Other crystallographic material (hydrogen coordinates, thermal parameters) have been deposited at the Cambridge Crystallographic Data Centre.

Table 2 Selected bond lengths (Å) and angles (°) for compound **18** with esds in parentheses[a]

O(1)–C(1)	1.414(3)	C(1)–C(2)	1.524(4)	C(5)–C(6)–O(28)	104.3(2)	C(7)–C(6)–O(28)	115.0(2)
C(1)–C(10)	1.539(5)	C(1)–O(19′)	1.430(3)	C(6)–C(7)–C(8)	105.3(2)	C(6)–C(7)–S(1′)	115.2(2)
C(2)–C(3)	1.555(4)	C(3)–C(4)	1.566(5)	C(8)–C(7)–S(1′)	106.4(2)	C(6)–C(7)–S(3′)	112.1(2)
C(3)–Si(3)	1.894(3)	C(4)–C(5)	1.536(4)	C(8)–C(7)–S(3′)	105.9(2)	S(1′)–C(7)–S(3′)	111.1(2)
C(4)–C(20)	1.527(4)	C(4)–C(28)	1.554(4)	C(7)–C(8)–C(9)	115.2(2)	C(8)–C(9)–O(9)	105.5(2)
C(5)–C(6)	1.493(5)	C(5)–C(10)	1.521(4)	C(8)–C(9)–C(10)	110.8(2)	O(9)–C(9)–C(10)	113.6(2)
C(6)–C(7)	1.544(4)	C(6)–O(28)	1.441(3)	C(1)–C(10)–C(5)	105.6(2)	C(1)–C(10)–C(9)	115.9(3)
C(7)–C(8)	1.545(4)	C(7)–S(1′)	1.827(3)	C(5)–C(10)–C(9)	103.0(2)	C(1)–C(10)–C(19)	103.6(2)
C(7)–S(3′)	1.827(4)	C(8)–C(9)	1.540(5)	C(5)–C(10)–C(19)	117.3(2)	C(9)–C(10)–C(19)	111.8(2)
C(9)–O(9)	1.430(3)	C(9)–C(10)	1.543(4)	C(10)–C(19)–C(19′)	105.3(3)	C(19)–C(19′)–O(19′)	106.4(2)
C(10)–C(19)	1.546(4)	C(19)–C(19′)	1.517(5)	C(1)–O(19′)–C(19′)	108.0(2)	C(4)–C(28)–O(28)	109.1(2)
C(19′)–O(19′)	1.437(4)	C(28)–O(28)	1.441(4)	C(6)–O(28)–C(28)	109.6(2)	C(7)–S(1′)–C(1′)	104.6(2)
S(1′)–C(1′)	1.811(4)	C(1′)–C(2′)	1.511(7)	S(1′)–C(1′)–C(2′)	114.9(3)	C(1′)–C(2′)–C(3′)	112.8(3)
C(2′)–C(3′)	1.526(6)	C(3′)–S(3′)	1.817(4)	C(2′)–C(3′)–S(3′)	113.4(3)	C(7)–S(3′)–C(3′)	101.7(2)
O(51)–C(51)	1.416(4)	C(51)–C(52)	1.523(4)	O(51)–C(51)–C(52)	111.9(3)	O(51)–C(51)–C(60)	108.0(2)
C(51)–C(60)	1.547(4)	C(51)–O(69′)	1.428(4)	C(52)–C(51)–C(60)	114.4(2)	O(51)–C(51)–O(69′)	110.3(2)
C(52)–C(53)	1.555(4)	C(53)–C(54)	1.569(4)	C(52)–C(51)–O(69′)	106.9(2)	C(60)–C(51)–O(69′)	104.4(3)
C(53)–Si(53)	1.894(3)	C(54)–C(55)	1.527(3)	C(51)–C(52)–C(53)	115.3(3)	C(52)–C(53)–C(54)	111.3(2)
C(54)–C(70)	1.521(5)	C(54)–C(78)	1.558(4)	C(52)–C(53)–Si(53)	109.8(2)	C(54)–C(53)–Si(53)	119.1(2)
C(55)–C(56)	1.495(4)	C(55)–C(60)	1.526(4)	C(53)–C(54)–C(55)	108.1(2)	C(53)–C(54)–C(70)	112.6(2)
C(56)–C(57)	1.534(4)	C(56)–O(78)	1.439(3)	C(55)–C(54)–C(70)	116.1(2)	C(53)–C(54)–C(78)	119.3(2)
C(57)–C(58)	1.548(4)	C(57)–S(51′)	1.828(4)	C(55)–C(54)–C(78)	96.1(2)	C(70)–C(54)–C(78)	104.0(3)
C(57)–S(53′)	1.829(3)	C(58)–C(59)	1.535(4)	C(54)–C(55)–C(56)	107.4(2)	C(54)–C(55)–C(60)	121.8(2)
C(59)–O(59)	1.430(3)	C(59)–C(60)	1.544(4)	C(56)–C(55)–C(60)	115.8(2)	C(55)–C(56)–C(57)	109.4(3)
C(60)–C(69)	1.546(5)	C(69)–C(69′)	1.514(4)	C(55)–C(56)–O(78)	104.4(2)	C(57)–C(56)–O(78)	116.0(2)
C(69′)–O(69′)	1.449(4)	C(78)–O(78)	1.450(3)	C(56)–C(57)–C(58)	106.0(2)	C(56)–C(57)–S(51′)	138.8(2)
S(51′)–C(51′)	1.817(4)	C(51′)–C(52′)	1.515(6)	C(58)–C(57)–S(51′)	107.4(2)	C(56)–C(57)–S(53′)	112.8(2)
C(52′)–C(53′)	1.512(7)	C(53′)–S(53′)	1.808(4)	C(58)–C(57)–S(53′)	104.9(2)	S(51′)–C(57)–S(53′)	111.2(2)
				C(57)–C(58)–C(59)	116.7(2)	C(58)–C(59)–O(59)	105.8(2)
O(1)–C(1)–C(2)	111.1(2)	O(1)–C(1)–C(10)	109.3(2)	C(58)–C(59)–C(60)	110.4(3)	O(59)–C(59)–C(60)	113.3(2)
C(2)–C(1)–C(10)	114.5(3)	O(1)–C(1)–O(19′)	110.1(2)	C(51)–C(60)–C(55)	105.9(2)	C(51)–C(60)–C(59)	115.2(3)
C(2)–C(1)–O(19′)	107.1(2)	C(10)–C(1)–O(19′)	104.5(2)	C(55)–C(60)–C(59)	102.3(2)	C(51)–C(60)–C(69)	103.5(2)
C(1)–C(2)–C(3)	115.8(3)	C(2)–C(3)–C(4)	111.1(2)	C(55)–C(60)–C(69)	117.4(3)	C(59)–C(60)–C(69)	112.8(2)
C(2)–C(3)–Si(3)	109.1(2)	C(4)–C(3)–Si(3)	118.9(2)	C(60)–C(69)–C(69′)	105.7(2)	C(69)–C(69′)–O(69′)	106.2(3)
C(3)–C(4)–C(5)	107.1(2)	C(3)–C(4)–C(20)	109.6(3)	C(51)–O(69′)–C(69′)	108.5(2)	C(54)–C(78)–O(78)	106.9(2)
C(5)–C(4)–C(20)	116.9(2)	C(3)–C(4)–C(28)	119.0(2)	C(56)–O(78)–C(78)	109.3(2)	C(57)–S(51′)–C(51′)	104.2(2)
C(5)–C(4)–C(28)	97.2(2)	C(20)–C(4)–C(28)	107.1(2)	S(51′)–C(51′)–C(52′)	114.8(3)	C(51′)–C(52′)–C(53′)	112.9(3)
C(4)–C(5)–C(6)	107.7(2)	C(4)–C(5)–C(10)	120.8(3)	C(52′)–C(53′)–S(53′)	113.3(3)	C(57)–C(53′)–C(53′)	102.3(2)
C(6)–C(5)–C(10)	116.7(2)	C(5)–C(6)–C(7)	108.7(2)				

[a] The atom numbering of the second independent molecule is mole $n + 50$.

Table 3 Atomic co-ordinates ($\times 10^4$) for compound **50**

Atom	x	y	z
C(1)	4 799(3)	3 852(3)	7 151(2)
O(1)	4 751(2)	5 021(2)	8 251(1)
C(2)	5 311(3)	4 599(3)	6 288(2)
C(3)	7 188(3)	5 542(3)	6 566(2)
O(3)	7 348(2)	6 892(2)	7 574(1)
C(4)	8 569(3)	4 527(2)	6 689(2)
C(5)	7 947(3)	3 832(2)	7 554(2)
C(6)	9 520(3)	3 257(2)	7 944(2)
O(6)	11 005(2)	4 353(2)	7 950(1)
C(7)	9 281(3)	3 160(2)	9 114(2)
O(7)	10 525(3)	3 270(2)	9 814(1)
C(8)	7 373(3)	3 004(3)	9 366(2)
C(9)	5 890(3)	2 304(2)	8 337(2)
C(10)	6 145(3)	2 842(2)	7 307(2)
C(11)	5 873(3)	1 338(2)	6 263(2)
O(11)	4 894(2)	218(2)	6 620(1)
C(12)	5 607(3)	550(2)	7 779(2)
O(12)	7 241(2)	49(2)	7 842(1)
C(13)	4 250(3)	−257(2)	8 301(2)
O(13)	4 532(3)	−1 257(2)	8 625(2)
O(14)	2 761(2)	314(2)	8 376(2)
C(14)	1 457(3)	−210(3)	8 985(3)
C(15)	10 431(3)	5 311(3)	7 354(2)
C(16)	8 745(3)	3 434(3)	5 484(2)
O(16)	8 015(3)	3 447(2)	4 608(1)
O(17)	9 853(2)	2 462(2)	5 485(1)
C(17)	10 106(4)	1 419(3)	4 357(2)

mmol) in THF (160 cm^3) under argon at −30 °C. The dark red solution was stirred for 35 min between −30 and −25 °C and was then cooled to −78 °C. A solution of propynal diethyl acetal **2** (6.85 g, 53.4 mmol) in THF (4 cm^3) was added *via* cannula during 1 h and the mixture was stirred at −78 °C for a further 1 h. After addition of triethyl phosphite (1.14 cm^3, 6.65 mmol) a stream of dry carbon dioxide (passed through a column of $CaCl_2$) was passed through the vigorously stirred mixture for 20 min, while keeping the temperature below −70 °C. The reaction mixture was allowed to warm to room temperature during 24 h (**NOTE**: allow for the evolution of a large volume of gas) and then dimethyl sulfate (21 cm^3, 220 mmol) was introduced *via* syringe. After 10 h, further dimethyl sulfate (6.5 cm^3, 68.7 mmol) was added and the mixture was stirred for a further 24 h. The dark grey suspension was poured slowly into saturated aq. NH_4Cl buffer (200 cm^3 of a 1:1 mixture of saturated aq. NH_4Cl and conc. NH_3) and extracted with diethyl ether (3 × 150 cm^3). The combined extracts were washed with brine (70 cm^3), dried (Na_2SO_4), and concentrated under reduced pressure. Purification of the residue by flash chromatography (7% diethyl ether–light petroleum) gave the *methyl acrylate derivative* **3** (13.8 g, 80%) as an oil; ν_{max}(film)/cm^{-1} 3067w, 3047w, 2974s, 2951m, 2896m, 1723s, 1611m, 1427m, 1301s, 1208s, 1114s, 1064s, 830s, 734m and 701m; δ_H(270 MHz) 7.51 (2 H, m, Ph), 7.34 (3 H, m, Ph), 6.74 (1 H, d, *J* 1.0, 3-H), 5.27 [1 H, d, *J* 1.0, $(EtO)_2CH$], 3.75–3.45 (4 H, m, 2 × $MeCH_2O$), 3.50 (3 H, s, CO_2Me), 1.22 (6 H, t, *J* 7.0, 2 × $MeCH_2O$) and 0.42 (6 H, s, 2 × Me); *m/z* (EI) 307 (M^+ − Me, 33%), 277 (M^+ − OEt, 23), 263 (M^+ − CO_2Me, 38), 245 (M^+ − Ph, 25), 233 (16), 201 (21), 135 ($PhMe_2Si^+$, 51) and 103 [$CH(OEt)_2^+$, 100] (Found: C, 63.35; H, 8.0. $C_{17}H_{26}O_4Si$ requires C, 63.3; H, 8.1%).

Table 4 Selected bond lengths (Å) and angles (°) for compound **50** with esds in parentheses

C(1)–O(1)	1.435(2)	C(1)–C(2)	1.532(4)
C(1)–C(10)	1.543(3)	C(2)–C(3)	1.536(3)
C(3)–O(3)	1.428(2)	C(3)–C(4)	1.556(3)
C(4)–C(5)	1.525(3)	C(4)–C(15)	1.545(3)
C(4)–C(16)	1.523(3)	C(5)–C(6)	1.503(3)
C(5)–C(10)	1.509(3)	C(6)–O(6)	1.435(3)
C(6)–C(7)	1.517(3)	O(6)–C(15)	1.452(3)
C(7)–O(7)	1.212(3)	C(7)–C(8)	1.515(3)
C(8)–C(9)	1.538(3)	C(9)–C(10)	1.558(3)
C(9)–C(12)	1.541(3)	C(10)–C(11)	1.533(3)
C(11)–O(11)	1.438(3)	O(11)–C(12)	1.416(3)
C(12)–O(12)	1.402(3)	C(12)–C(13)	1.527(4)
O(1)–C(1)–C(2)	109.1(2)	O(1)–C(1)–C(10)	108.6(2)
C(2)–C(1)–C(10)	111.6(2)	C(1)–C(2)–C(3)	115.2(2)
C(2)–C(3)–O(3)	111.8(2)	C(2)–C(3)–C(4)	109.3(2)
O(3)–C(3)–C(4)	111.6(2)	C(3)–C(4)–C(5)	106.0(2)
C(3)–C(4)–C(15)	118.7(2)	C(5)–C(4)–C(15)	96.8(2)
C(3)–C(4)–C(16)	108.1(2)	C(5)–C(4)–C(16)	117.5(2)
C(15)–C(4)–C(16)	109.9(2)	C(4)–C(5)–C(6)	105.8(2)
C(4)–C(5)–C(10)	120.0(2)	C(6)–C(5)–C(10)	118.1(2)
C(5)–C(6)–O(6)	103.4(2)	C(5)–C(6)–C(7)	108.3(2)
O(6)–C(6)–C(7)	114.8(2)	C(6)–O(6)–C(15)	109.7(2)
C(6)–C(7)–O(7)	122.5(2)	C(6)–C(7)–C(8)	114.8(2)
O(7)–C(7)–C(8)	122.6(2)	C(7)–C(8)–C(9)	118.2(2)
C(8)–C(9)–C(10)	115.3(2)	C(8)–C(9)–C(12)	114.6(2)
C(10)–C(9)–C(12)	104.0(2)	C(1)–C(10)–C(5)	105.5(2)
C(1)–C(10)–C(9)	113.5(2)	C(5)–C(10)–C(9)	108.1(2)
C(1)–C(10)–C(11)	110.5(2)	C(5)–C(10)–C(11)	116.3(2)
C(9)–C(10)–C(11)	103.1(2)	C(10)–C(11)–O(11)	105.7(2)
C(11)–O(11)–C(12)	106.0(1)	C(9)–C(12)–O(11)	104.5(2)
C(9)–C(12)–O(12)	109.5(2)	O(11)–C(12)–O(12)	111.5(2)
C(9)–C(12)–C(13)	113.9(2)	O(11)–C(12)–C(13)	107.0(2)
O(12)–C(12)–C(13)	110.3(2)	C(4)–C(15)–O(6)	107.1(2)

(E)-3-*Dimethyl(phenyl)silyl*-2-*hydroxymethylprop*-2-*enal* **5**.—DIBAL (96 cm^3 of a 1.5 mol dm^{-3} solution in toluene, 144 mmol) was added *via* cannula to a stirred solution of the ester **3** (16.56 g, 51.35 mmol) in THF (420 cm^3) at −78 °C. The clear solution was warmed to −25 °C and was kept at that temperature for 12 h. The reaction was then quenched by careful addition of water (20 cm^3) to the vigorously stirred mixture, which was then warmed slowly to room temperature. Ethyl acetate (200 cm^3) and $NaHCO_3$ (excess) were added and the mixture was stirred for 2 h. The solid was filtered off under suction, and then washed exhaustively with ethyl acetate, and the filtrate was evaporated under reduced pressure to obtain the crude *alcohol* **4** (15 g) as a pale yellow oil, sufficiently pure for use in the next step. An analytical sample was purified by column chromatography (35% diethyl ether–light petroleum); ν_{max}(film)/cm^{-1} 3452m, 3066w, 3047w, 2973s, 2928m, 2876m, 1625w, 1426m, 1249m, 1148m, 1113s, 1056s, 839s, 731m and 700m; δ_H(270 MHz) 7.58–7.50 (2 H, m, Ph), 7.40–7.31 (3 H, m, Ph), 5.95 (1 H, d, *J* 0.9, 3-H), 4.86 (1 H, d, *J* 0.9, 1-H), 4.14 (2 H, d, *J* 6.1, allylic CH_2OH), 3.73–3.41 (4 H, m, 2 × MeCH_2O), 2.39 (1 H, t, *J* 6.1, OH), 1.24 (6 H, t, *J* 7.1, 2 × MeCH_2O) and 0.45 (6 H, s, 2 × Me); *m/z* (EI) 279 (M^+ − Me, 1.3%), 263 (M^+ − CH_2OH, 0.3), 249 (M^+ − OEt, 0.6), 233 (1.4), 217 (M^+ − Ph, 1.4), 189 (23), 159 (M^+ − $PhMe_2Si$, 4.1), 135 ($PhMe_2Si^+$, 100) and 103 [$CH(OEt)_2^+$, 42] (Found: C, 65.5; H, 9.1. $C_{16}H_{26}O_3Si$ requires C, 65.3; H, 8.9%).

A solution of the crude alcohol **4** (15 g) and PTSA monohydrate (800 mg, 4.2 mmol) in 2% water–acetone (370 cm^3) was stirred for 2 h, then poured into saturated aq. $NaHCO_3$ (100 cm^3) and extracted with diethyl ether (3 × 250 cm^3). The combined extracts were washed with brine (200 cm^3), dried ($MgSO_4$), and concentrated under reduced pressure.

Table 5 Atomic co-ordinates (× 10^4) for compound (+)-**53**

Atom	*x*	*y*	*z*
O(1)	9 595(3)	−1 262(3)	9 775(1)
C(1)	8 843(5)	−998(4)	10 217(2)
C(2)	9 442(6)	−58(5)	10 515(2)
C(3)	9 639(5)	928(5)	10 154(2)
O(3)	10 311(3)	556(3)	9 711(1)
C(4)	8 321(5)	1 342(4)	9 987(2)
C(5)	7 667(5)	369(3)	9 748(2)
C(6)	6 644(5)	811(4)	9 427(2)
C(7)	6 394(5)	−21(4)	9 001(2)
O(7)	7 279(3)	77(3)	8 604(1)
C(8)	6 458(4)	−1 168(4)	9 214(2)
C(9)	6 960(5)	−1 491(4)	9 643(2)
C(10)	7 499(4)	−708(4)	10 038(2)
C(11)	6 663(5)	−729(5)	10 525(2)
C(12)	5 282(6)	−681(6)	10 432(2)
O(12)	4 759(4)	−664(3)	10 950(1)
C(13)	3 548(6)	−597(5)	10 984(2)
O(13)	2 884(4)	−600(5)	10 625(1)
C(14)	3 123(4)	−518(4)	11 531(2)
C(15)	3 645(14)	530(9)	11 744(6)
C(16)	3 686(14)	−1 463(10)	11 815(5)
C(17)	1 743(7)	−527(14)	11 592(6)
C(15′)	2 565(18)	609(8)	11 594(7)
C(16′)	4 058(14)	−702(19)	11 945(6)
C(17′)	2 087(12)	−1 345(11)	11 590(7)
C(28)	8 255(7)	2 109(4)	9 517(2)
O(28)	7 121(4)	1 864(3)	9 254(1)
C(31)	10 651(5)	−583(5)	9 712(2)
C(32)	11 245(4)	−856(4)	9 206(2)
C(33)	10 562(5)	−905(5)	8 776(2)
C(34)	11 125(5)	−1 149(6)	8 309(2)
C(35)	12 379(6)	−1 348(5)	8 287(3)
C(36)	13 049(6)	−1 321(6)	8 726(3)
C(37)	12 510(5)	−1 065(5)	9 187(2)
C(41)	7 585(9)	1 892(6)	10 421(3)
O(41)	6 492(7)	1 847(5)	10 446(2)
O(42)	8 492(7)	2 445(4)	10 725(2)
C(43)	8 482(9)	3 004(6)	11 113(3)
Si	7 198(1)	819(1)	8 077(1)
C(71)	8 721(5)	1 508(4)	8 011(2)
C(72)	5 909(6)	1 838(5)	8 104(3)
C(73)	6 918(6)	−137(6)	7 529(2)
C(74)	8 000(8)	−957(6)	7 495(2)
C(75)	5 727(8)	−803(7)	7 622(3)
C(76)	6 827(8)	494(6)	7 028(2)

Flash chromatography of the residue (30% diethyl ether–light petroleum) gave the *aldehyde* **5** (8.66 g, 77% from **3**) as an oil; ν_{max}(film)/cm^{-1} 3442m, 3067m, 3047m, 2954m, 2897m, 2812m, 2712w, 1681s, 1601w, 1427m, 1250m, 1135m, 1112m, 1023m, 840s, 734m and 701m; δ_H(270 MHz) 9.48 (1 H, s, 1-H), 7.60–7.50 (2 H, m, Ph), 7.45–7.33 (3 H, m, Ph), 6.99 (1 H, s, 3-H), 4.30 (2 H, d, *J* 6.6, allylic CH_2OH), 2.27 (1 H, t, *J* 6.6, OH) and 0.54 (6 H, s, 2 × Me); *m/z* (EI) 220 (M^+, 1%), 219 (M^+ − H, 5.2), 205 (M^+ − Me, 100), 187 (M^+ − Me − H_2O, 27), 143 (M^+ − Ph, 41), 135 ($PhMe_2Si^+$, 61) and 77 (Ph^+, 62) (Found: M^+ − Me, 205.0688. $C_{11}H_{13}O_2Si$ requires *m/z*, 205.0685).

(Z)-*Methyl* 2-*Bromomethyl*-3-*dimethyl(phenyl)silylprop*-2-*enoate* **6**.—KH_2PO_4 (21.5 g, 0.158 mol) and K_2HPO_4 (170 mg, 0.98 mmol) were added to a vigorously stirred mixture of the aldehyde **5** (7 g, 31.77 mmol) and 2-methylbut-2-ene (34 cm, 0.32 mol) in *tert*-butyl alcohol–water (1:1; 84 cm^3) at 0 °C, followed by sodium chlorite (9 g of 80% pure material, 79.5 mmol). The yellow reaction mixture was allowed to warm and was cooled only occasionally to keep the temperature below 30 °C. After 1.5 h the yellow colour had faded and the mixture was re-cooled to 0 °C before saturated aq. Na_2SO_3 (15 cm^3) was added,

Table 6 Selected bond lengths (Å) and angles (°) for compound (+)-**53** with esds in parentheses

O(1)–C(1)	1.444(6)	O(1)–C(31)	1.408(7)
C(1)–C(2)	1.524(8)	C(1)–C(10)	1.552(7)
C(2)–C(3)	1.539(8)	C(3)–O(3)	1.437(6)
C(4)–C(4)	1.560(8)	O(3)–C(31)	1.430(7)
C(4)–C(5)	1.509(7)	C(4)–C(28)	1.543(7)
C(4)–C(41)	1.536(9)	C(5)–C(6)	1.481(7)
C(5)–C(10)	1.522(6)	C(6)–O(28)	1.449(6)
C(6)–C(7)	1.528(7)	O(28)–C(28)	1.426(8)
C(7)–O(7)	1.410(5)	C(7)–C(8)	1.502(7)
C(8)–C(9)	1.303(7)	C(9)–C(10)	1.517(6)
C(10)–C(11)	1.556(6)	C(31)–C(32)	1.507(7)
C(1)–O(1)–C(31)	114.2(4)	O(1)–C(1)–C(2)	110.0(4)
O(1)–C(1)–C(10)	108.9(4)	C(2)–C(1)–C(10)	112.0(4)
C(1)–C(2)–C(3)	109.0(4)	C(2)–C(3)–O(3)	108.7(4)
C(2)–C(3)–C(4)	107.4(4)	O(3)–C(3)–C(4)	109.0(4)
C(3)–O(3)–C(31)	115.3(4)	C(3)–C(4)–C(5)	106.5(4)
C(3)–C(4)–C(28)	117.4(5)	C(5)–C(4)–C(28)	97.0(4)
C(3)–C(4)–C(41)	113.3(5)	C(5)–C(4)–C(41)	114.1(4)
C(28)–C(4)–C(41)	107.6(5)	C(4)–C(5)–C(6)	107.1(4)
C(4)–C(5)–C(10)	121.4(4)	C(6)–C(5)–C(10)	120.5(4)
C(5)–C(6)–O(28)	103.7(4)	C(5)–C(6)–C(7)	107.7(4)
O(28)–C(6)–C(7)	114.7(4)	C(6)–O(28)–C(28)	109.5(4)
C(6)–C(7)–O(7)	111.3(4)	C(6)–C(7)–C(8)	109.5(4)
O(7)–C(7)–C(8)	108.8(4)	C(7)–O(7)–Si	128.8(3)
C(7)–C(8)–C(9)	128.1(5)	C(8)–C(9)–C(10)	123.6(4)
C(1)–C(10)–C(5)	103.6(4)	C(1)–C(10)–C(9)	114.5(4)
C(5)–C(10)–C(9)	104.1(3)	C(1)–C(10)–C(11)	106.4(4)
C(5)–C(10)–C(11)	119.3(4)	C(9)–C(10)–C(11)	109.2(4)
C(4)–C(28)–O(28)	107.3(5)	O(1)–C(31)–O(3)	111.2(4)

followed by water (30 cm^3). The mixture was extracted with CH_2Cl_2 (1 × 150, 2 × 100 cm^3), and the combined organic layers were dried ($MgSO_4$) and evaporated to obtain the crude acid. A stream of CH_2N_2/argon (generated† from 3 × 3.3 g Diazald®) was passed through a solution of the acid in CH_2Cl_2 (150 cm^3) until TLC showed absence of the starting material. The solution was evaporated under reduced pressure and the residue was purified by flash chromatography (40% diethyl ether–light petroleum) to obtain (E)-*methyl* 3-*dimethyl*-(*phenyl*)*silyl*-2-*hydroxymethylprop*-2-*enoate* (7.51 g, 94%) as an oil; ν_{max}(film)/cm^{-1} 3468m, 3067w, 3047w, 2952m, 2897m, 1707s, 1606m, 1427m, 1330m, 1240s, 1114m, 1023m, 824s, 785m, 733m and 701m; δ_H(270 MHz) 7.58–7.47 (2 H, m, Ph), 7.42–7.32 (3 H, m, Ph), 7.17 (1 H, s, 3-H), 4.28 (2 H, d, *J* 6.8, allylic CH_2OH), 3.79 (3 H, s, CO_2Me), 2.29 (1 H, t, *J* 6.8, OH) and 0.48 (6 H, s, 2 × Me); *m/z* (EI) 250 (M^+, 0.1%), 249 (M^+ − H, 0.6), 235 (M^+ − Me, 66), 219 (M^+ − OMe, 5.3), 217 (M^+ − Me − H_2O, 10.6), 173 (M^+ − Ph, 27) and 135 ($PhMe_2Si^+$, 30) (Found: C, 62.5; H, 7.3. $C_{13}H_{18}O_3Si$ requires C, 62.4; H, 7.25%).

NBS (7.1 g, 39.9 mmol) was added portionwise to a solution of (*E*)-methyl 3-dimethyl(phenyl)silyl-2-hydroxymethylprop-2-enoate (7.99 g, 31.91 mmol) and triphenylphosphine (11.7 g, 44.6 mmol) in CH_2Cl_2 (150 cm^3) until the yellow colour persisted. The reaction mixture was cooled occasionally during the addition to maintain the temperature below 25 °C. After completion of addition, the solvent was evaporated off under reduced pressure and the residue was purified by flash chromatography (5% diethyl ether–light petroleum) to obtain the *bromomethacrylate* **6** (6.93 g, 69%) as an oil; ν_{max}(film)/ cm^{-1} 3067w, 3048w, 2952m, 1721s, 1600m, 1427m, 1336m, 1238s, 1153m, 1114m, 1064m, 888m, 839s, 785s, 734m and 701m; δ_H(270 MHz) 7.58–7.50 (2 H, m, Ph), 7.45–7.32 (3 H, m, Ph), 7.22 (1 H, s, 3-H), 4.12 (2 H, s, allylic CH_2Br), 3.81 (3 H, s, CO_2Me) and 0.53 (6 H, s, 2 × Me); *m/z* (EI) 312 (M^+, 0.7%), 311 (M^+ − H, 2), 297 (M^+ − Me, 17.6), 281 (M^+ − OMe, 1.8), 233 (M^+ − Br, 53) and 135 ($PhMe_2Si^+$, 100) (Found: M^+ − H, 311.0096. $C_{13}H_{16}BrO_2Si$ requires *m/z* 311.0103).

† Prepared according to ref. 41.

2-tert-*Butyldimethylsiloxy*-1-[2′-(2′,2″-*dimethoxyethyl*)-1′,3′-*dithian*-2′-*yl*]*ethanol* **9**.—*N,N,N′,N′*-Tetramethylethylenediamine (40 cm^3, 0.265 mol) was added to a stirred solution of 2-(2,2-dimethoxyethyl)-1,3-dithiane **8**[12] (55 g, 0.264 mol) in THF (500 cm^3) at −30 °C under argon, followed by butyllithium (110 cm^3 of a 2.5 mol dm^{-3} solution in hexanes, 0.275 mol). After 90 min, the deep red solution was cooled to − 78 °C and a solution of 2-(*tert*-butyldimethylsiloxy)ethanal **7**[19] (44 g, 0.252 mol) in THF (100 cm^3) was added *via* cannula. After 5 min, a solution of acetic acid (16.5 g, 0.275 mol) in THF (50 cm^3) was added slowly, the mixture was warmed to room temperature, then poured into water (400 cm^3) and extracted with diethyl ether (1 × 400, 2 × 200 cm^3). The combined ether layers were washed with brine (200 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. Purification of the residue by flash chromatography (gradient elution, 10–30% diethyl ether–light petroleum) gave the *alcohol* **9** (52.5 g, 54%) as an oil; ν_{max}(film)/cm^{-1} 3484m, 2925s, 2854s, 2830m, 1461m, 1423m, 1360m, 1252s, 1190m, 1118s, 1076s, 837s and 778s; δ_H(270 MHz) 4.77 (1 H, dd, *J* 3.9, 5.4, 2″-H), 4.13 (1 H, ddd, *J* 0.8, 2.6, 10.3, 2-H), 3.98 (1 H, dt, *J* 7.8, 2.9, 1-H), 3.80 (1 H, dd, *J* 7.8, 10.3, 2-H), 3.37 (3 H, s, OMe), 3.35 (3 H, s, OMe), 3.22 (1 H, dd, *J* 0.7, 2.9, OH), 3.01–2.85 (2 H, m, CH_2S), 2.83–2.71 (2 H, m, CH_2S), 2.39 (1 H, dd, *J* 5.4, 15.1, 1″-H), 2.12 (1 H, dd, *J* 3.7, 15.14, 1″-H), 2.03–1.91 (2 H, m, 2 × 5′-H), 0.92 (9 H, s, Bu^t) and 0.10 (6 H, s, 2 × Me); *m/z* (EI) 382 (M^+, 0.4), 350 (M^+ − MeOH, 0.6), 293 [M^+ − $CH_2CH(OMe)_2$, 2], 237 (M^+ − $CH_2OTBDMS$, 3.2), 235 (15), 207 [$(C_3H_6S_2)CCH_2CH(OMe)_2^+$, 19], 187 (12), 176 (27), 145 ($CH_2OTBDMS^+$, 6.5), 119 (12), 89 [$CH_2CH(OMe)_2^+$, 8] and 75 [Me_2SiOH^+ and $CH(OMe)_2^+$, 100] (Found: C, 50.0; H, 9.0. $C_{16}H_{34}O_4S_2Si$ requires C, 50.2; H, 9.9%).

(E)-*Methyl* 2-{2′-tert-*Butyldimethylsiloxy*-1′-[2″-(2‴,2⁗-*dimethoxyethyl*)-1″,3″-*dithian*-2″-*yl*]*ethoxymethyl*}-3-*dimethyl*-(*phenyl*)*silylprop*-2-*enoate* **10** *and* (R*,RS)-*Methyl* 2-{{2′-tert-*Butyldimethylsiloxy*-1′-[2″,2‴,2⁗-*dimethoxyethyl*)-1″,3″-*dithian*-2″-*yl*]*ethoxy*}[*dimethyl*(*phenyl*)*silyl*]*methyl*}*prop*-2-*enoate* **11**.—A solution of the alcohol **9** (6.5 g, 17.0 mmol) in THF (30 cm^3) was added *via* cannula to a stirred suspension of KH (2.7 g of a 35% dispersion in oil, 23.6 mmol) in THF (80 cm^3). The suspension was stirred at room temperature until H_2 evolution ceased (1 h), then was cooled to 0 °C and a solution of the bromomethacrylate **6** (5.53 g, 17.7 mmol) in THF (30 cm^3) was introduced *via* cannula. The mixture was stirred at 0 °C for 20 min and was then allowed to warm to room temperature for a further 10 min. The reaction was quenched by careful addition of saturated aq. NH_4Cl (10 cm^3) and water (30 cm^3). Extraction with diethyl ether (3 × 60 cm^3) and washing of the combined extracts with brine (50 cm^3), followed by drying ($MgSO_4$) and evaporation of the solvent under reduced pressure gave a yellow oil. Purification by flash chromatography (20% diethyl ether–light petroleum) gave, in order of elution, the *ether* **11** (1.89 g, 18%, inseparable 2.2:1 mixture of diastereoisomers) as an oil; ν_{max}(film)/cm^{-1} 3067w, 3046w, 2950s, 2929s, 2854m, 2828m, 1718s, 1617w, 1460m, 1426m, 1254s, 1193m, 1114s, 1074s, 837s, 778m, 734m and 701m; δ_H(500 MHz, diastereoisomers denoted as 'a' and 'b') 7.55–7.49 (2.9 H, m, $Ph_{a,b}$), 7.37–7.27 (4.35 H, m, $Ph_{a,b}$), 6.30 (0.45 H, d, *J* 1.8, 3-H_b), 6.18 (1 H, d, *J* 1.7, 3-H_a), 6.08 (0.45 H, t, *J* 1.5, 3-H_b), 5.71 (1 H, t, *J* 1.5, 3-H_a), 5.06 (1 H, d, *J* 1.0, allylic CH_a), 5.04 (0.45 H, br s, allylic CH_b), 4.79 (1 H, t, *J* 4.3, 2‴-H_a), 4.76 (0.45 H, dd, *J* 4.0, 4.7, 2‴-H_b), 4.19 (0.45 H, dd, *J* 2.2, 11.4, 2′-H_b), 4.10 (1 H, dd, *J* 2.4, 10.9, 2′-H_a),

3.84 (1 H, dd, J 2.4, 4.4, 1′-H_a), 3.77 (0.45 H, dd, J 2.3, 4.1, 1′-H_b), 3.72 (1 H, dd, J 4.4, 10.9, 2′-H_a), 3.58 (0.45 H, dd, J 4.1, 11.4, 2′-H_b), 3.50 (1.35 H, s, CO_2Me_b), 3.45 (3 H, s, CO_2Me_a), 3.35 (3 H, s, OMe_a), 3.33 (1.35 H, s, OMe_b), 3.32 (3 H, s, OMe_a), 3.31 (1.35 H, s, OMe_b), 2.93–2.78 [2.9 H, m, (4″- and 6″-H)$_{a,b}$], 2.65–2.52 [2.9 H, m, (4″- and 6″-H)$_{a,b}$], 2.31 (1 H, dd, J 4.1, 15.3, 1‴-H_a), 2.27 (0.45 H, dd, J 3.8, 15.2, 1‴-H_b), 1.97 (1 H, dd, J 4.5, 15.3, 1‴-H_a), 1.90 (0.45 H, dd, J 4.8, 15.3, 1‴-H_b), 1.99–1.79 [2.9 H, m, (5″-H_2)$_{a,b}$], 0.87 (4.05 H, s, Bu^t_b), 0.85 (9 H, s, Bu^t_a), 0.40 (3 H, s, Me_a), 0.35 (1.35 H, s, Me_b), 0.32 (3 H, s, Me_a), 0.30 (1.35 H, s, Me_b), 0.02 (1.35 H, s, Me_b), 0.01 (1.35 H, s, Me_b), −0.011 (3 H, s, Me_a) and −0.013 (3 H, s, Me_a); m/z (EI) 614 (M^+, 0.4%), 599 (M^+ − Me, <0.1), 583 (M^+ − OMe, 0.4), 567 (M^+ − CH_2SH, 0.1), 557 (M^+ − Bu^t, 0.2), 537 (M^+ − Ph, <0.1), 525 [M^+ − $CH_2CH(OMe)_2$, <0.1], 233 ($C_{13}H_{17}O_2Si^+$, 20), 207 [$(C_3H_6S_2)CCH_2CH(OMe)_2^+$, 8], 135 ($PhMe_2Si^+$, 100) and 75 [$Me_2SiOH^+$ and $CH(OMe)_2^+$, 88] (Found: C, 56.7; H, 8.3. $C_{29}H_{50}O_6S_2Si_2$ requires C, 56.6; H, 8.2%); and the *ether* **10** (6.25 g, 60% as an oil; ν_{max}(film)/cm^{-1} 3066w, 3046w, 2950s, 2928s, 2854m, 1718s, 1609w, 1461m, 1427m, 1250s, 1224s, 1115s, 1078s, 838s, 779m, 733m and 701m; δ_H(500 MHz) 7.54 (2 H, m, Ph), 7.35 (3 H, m, Ph), 7.09 (1 H, s, 3-H), 4.73 (1 H, t, J 4.3, 2‴-H), 4.61 (1 H, d, J 11.1, allylic CH_2O), 4.38 (1 H, d, J 11.1, allylic CH_2O), 4.10 (1 H, dd, J 1.8, 10.3, 2′-H), 3.76 (3 H, s, CO_2Me), 3.79–3.70 (2 H, m, 1′- and 2′-H), 3.32 (3 H, s, OMe), 3.30 (3 H, s, OMe), 2.99–2.86 and 2.65–2.54 (4 H, m, 4″- and 6″-H_2), 2.20 (1 H, dd, J 4.0, 15.1, 1‴-H), 1.96 (H, dd, J 4.6, 15.1, 1‴-H), 1.95–1.89 (1 H, m, 5″-H), 1.88–1.79 (1 H, m, 5″-H), 0.87 (9 H, s, Bu^t), 0.50 (6 H, s, 2 × Me), 0.04 (3 H, s, Me) and 0.03 (3 H, s, Me); m/z (EI) 614 (M^+, 0.1%), 583 (M^+ − OMe, 0.3), 557 (M^+ − Bu^t, 0.1), 469 (M^+ − $CH_2OTBDMS$, 0.1), 407 [M^+ − $(C_3H_6S_2)CCH_2CH(OMe)_2$, 5.6], 233 ($C_{13}H_{17}O_2Si^+$, 8.8), 207 [$(C_3H_6S_2)CCH_2CH(OMe)_2^+$, 16], 135 ($PhMe_2Si^+$, 6.3), 89 [$CH_2CH(OMe)_2^+$, 13] and 75 [$Me_2SiOH^+$ and $CH(OMe)_2^+$, 100] (Found: C, 56.6; H, 8.4%).

(E)-*Methyl* 2-{[2″-(2‴,2⁗-*Dimethoxyethyl*)-1″,3″-*dithian*-2″-*yl*](*formyl*)*ethoxymethyl*}-3-*dimethyl*(*phenyl*)*silylprop*-2-*enoate* **12**.—Pyridine (25 cm^3, 310 mmol) was added to a solution of the silyl ether **10** (41.5 g, 67.5 mmol) in acetonitrile (330 cm^3) in a plastic flask. HF (12.5 cm^3 of a 40% aqueous solution, 287 mmol) was added *via* plastic syringe and the solution was stirred at room temperature for 10 h, then at 35 °C for a further 24 h. The reaction was quenched by careful addition of saturated aq. $NaHCO_3$ (200 cm^3) and water (200 cm^3) to the vigorously stirred mixture. After effervescence had ceased, the mixture was extracted with diethyl ether (1 × 500, 2 × 400 cm^3) and the combined organic layers were washed with brine (150 cm^3), dried ($MgSO_4$), and concentrated under reduced pressure. Flash chromatography of the residue (gradient elution, 50–60% diethyl ether–light petroleum) afforded (E)-*methyl* 2-{1′-[2″-(2‴,2⁗-*dimethoxyethyl*)-1″,3″-*dithian*-2″-*yl*]-2′-*hydroxyethoxymethyl*}-3-*dimethyl*(*phenyl*)-*silylprop*-2-*enoate* (28.7 g, 85%) as an oil; ν_{max}(film)/cm^{-1} 3480m, 3066w, 3045w, 2949s, 2828m, 1700s, 1608m, 1426m, 1344m, 1248s, 1230s, 1116s, 1081s, 820m, 786m, 735m and 702m; δ_H(500 MHz) 7.57–7.48 (2 H, m, Ph), 7.44–7.32 (3 H, m, Ph), 7.21 (1 H, s, 3-H), 4.74 (1 H, t, J 4.3, 2‴-H), 4.72 (1 H, d, J 10.2, allylic CH_2O), 4.36 (1 H, d, J 10.2, allylic CH_2O), 4.05 (1 H, dt, J 2.6, 10.8, 2′-H, obscured by OH), 4.02 (1 H, br d, J 10.8, OH), 3.93 (1 H, dd, J 2.6, 8.3, 1′-H), 3.79 (3 H, s, CO_2Me), 3.68 (1 H, br t, J 8.7, 2′-H), 3.31 (3 H, s, OMe), 3.29 (3 H, s, OMe), 2.94 (1 H, ddd, J 3.1, 10.7, 14.3, 4″- or 6″-H), 2.81 (1 H, ddd, J 3.0, 10.6, 14.4, 6″- or 4″-H), 2.67–2.54 (2 H, m, 4″- and 6″-H), 2.23 (1 H, dd, J 4.3, 15.2, 1‴-H), 2.04–1.94 (1 H, m, 5″-H), 1.90 (1 H, dd, J 4.4, 15.2, 1‴-H), 1.90–1.80 (1 H, m, 5″-H), 0.55 (3 H, s, Me) and 0.48 (3 H, s, Me); m/z (EI, 20 eV) 500 (M^+, <0.1%), 469 (M^+ − OMe, 0.1), 468 (M^+ − MeOH, 0.1), 437 (0.7), 293 [M^+ − $(C_3H_6S_2)CCH_2CH(OMe)_2$, 5.6], 233 ($C_{13}H_{17}O_2Si^+$, 6.4), 207 [$(C_3H_6S_2)CCH_2CH(OMe)_2^+$, 100] and 75 [$CH(OMe)_2^+$, 91] (Found: C, 55.1; H, 7.5. $C_{23}H_{36}O_6S_2Si$ requires C, 55.2; H, 7.25%).

Anhydrous DMSO (3.85 cm^3, 54.3 mmol) was added *via* syringe to a solution of oxalyl dichloride (2.35 cm^3, 26.9 mmol) in THF (58 cm^3) at −78 °C under argon. After being warmed to −35 °C for 3 min, the mixture was re-cooled to −78 °C and a solution of the (*E*)-methyl 2-{1-[2-(2,2-dimethoxyethyl)-1,3-dithian-2-yl]-2-hydroxyethoxymethyl}-3-dimethyl(phenyl)silylprop-2-enoate (10 g, 19.97 mmol) in THF (20 cm^3) was added *via* cannula. The solution was warmed to −35 °C for 20 min, then was re-cooled to −78 °C before triethylamine (8.1 cm^3, 58.1 mmol) was added and the opaque solution was allowed to warm to room temperature. The mixture was diluted with light petroleum (50 cm^3) and was then poured directly onto a silica column (200 g), and the crude product was eluted with 50% diethyl ether–light petroleum. Subsequent purification by flash chromatography (35% diethyl ether–light petroleum) gave the *aldehyde* **12** (9.3 g, 93%) as a pale yellow oil; ν_{max}(film)/cm^{-1} 3066w, 3045w, 2949m, 2830m, 1718s, 1608w, 1426m, 1226s, 1116s, 1077s, 837s, 792m, 735m and 702m; δ_H(500 MHz) 9.52 (1 H, d J 3.4, 2′-H), 7.56–7.49 (2 H, m, Ph), 7.42–7.32 (3 H, m, Ph), 7.23 (1 H, s, 3-H), 4.72 (1 H, t, J 4.7, 2‴-H), 4.34 (1 H, d, J 10.9, allylic CH_2O), 4.26 (1 H, d, J 10.9, allylic CH_2O), 3.95 (1 H, d, J 3.4, 1′-H), 3.76 (3 H, s, CO_2Me), 3.32 (3 H, s, OMe), 3.30 (3 H, s, OMe), 3.02–2.90 and 2.67–2.55 (4 H, m, 4″- and 6″-H_2), 2.27 (1 H, dd, J 4.7, 15.1, 1‴-H), 2.06 (1 H, dd, J 4.7, 15.1, 1‴-H), 2.03–1.95 (1 H, m, 5″-H), 1.90–1.80 (1 H, m, 5″-H), 0.5 (3 H, s, Me) and 0.49 (3 H, s, Me); m/z (EI) 498 (M^+, <0.1%), 469 (M^+ − CHO, 0.6), 467 (M^+ − OMe, 0.4), 452 (M^+ − OMe, 0.5), 438 (M^+ − MeOH − CO, 0.2), 233 ($C_{13}H_{17}O_2Si^+$, 5.1), 207 [$(C_3H_6S_2)CCH_2CH(OMe)_2^+$, 25], 135 ($PhMe_2Si^+$, 10.4) and 75 [$CH(OMe)_2^+$, 100] (Found: M^+, 498.1557. $C_{23}H_{34}O_6S_2Si$ requires M, 498.1566).

(E)-*Methyl* 2-{1′-[2″-(2‴,2⁗-*Dimethoxyethyl*)-1″,3″-*dithian*-2″-*yl*]-2′-[(E)-2⁗-*oxotetrahydrofuran*-3-*ylidene*]*ethoxymethyl*}-3-*dimethyl*(*phenyl*)*silylprop*-2-*enoate* **13** *and its Z-Isomer* **14**.—Anhydrous LiCl (flame dried; 4.4 g, 104 mmol) was added to a stirred solution of α-diethoxyphosphoryl-γ-butyrolactone[22] (19.5 g, 88 mol) in DMF (85 cm^3). Following addition of a solution of the aldehyde **12** (17 g, 34.1 mmol) in DMF (50, +2 × 5 cm^3 rinsing) *via* cannula, diisopropylethylamine (11.7 cm^3, 67 mmol) was introduced during 16 h using a syringe pump. The solution was stirred for a further 8 h and then further α-diethoxyphosphoryl-γ-butyrolactone (15.5 g, 69.8 mmol), dissolved in DMF (50 cm^3), and LiCl (2.9 g, 68 mmol) were added, followed by slow addition (20 h) of diisopropylethylamine (8.4 cm^3, 48.2 mmol). After completion of addition, the brown reaction mixture was poured into saturated aq. NH_4Cl (250 cm^3) and extracted with diethyl ether (3 × 250, 1 × 100 cm^3). The combined ether layers were washed with brine (130 cm^3), dried ($MgSO_4$), and concentrated under reduced pressure. Purification of the residue by flash chromatography (gradient elution, 50–85% diethyl ether–light petroleum) gave, in order of elution, the recovered aldehyde **12** (8.4 g, 49%) and a mixture of the *unsaturated lactones* **13** and **14** (9 g, 47%, ratio 2.7:1) as a pale yellow oil. The two geometric isomers were separated by column chromatography (70% diethyl ether–light petroleum) to obtain the *less polar isomer* **14** (2.46 g, 13%) as rhombohedral crystals; m.p. 98 °C (from Et_2O–light petroleum); ν_{max}(film)/cm^{-1} 2955m, 2922m, 28352, 1788s, 1751s, 1713s, 1436m, 1376m, 1224s, 1170m, 1116m, 1067s and 735m; δ_H(500 MHz) 7.54–7.49 (2 H, m, Ph), 740–7.33 (3 H, m, Ph), 7.13 (1 H, s, 3-H), 6.15 (1 H, dt, J 10.1, 2.4, 2′-H), 5.71 (1 H, d, J 10.1, 1′-H), 4.76 (1 H, t, J 4.3, 2‴-H), 4.38–4.27 (2 H, m, 5⁗-H_2), 4.28 (1 H, d, J 10.1, allylic CH_2O), 4.13 (1 H, d, J 10.1, allylic CH_2O), 3.74 (3 H,

s, CO_2Me), 3.35 (3 H, s, OMe), 3.33 (3 H, s, OMe), 3.14 (1 H, ddd, *J* 3.0, 10.7, 14.0, 4″- or 6″-H), 3.04 (1 H, ddd, *J* 2.8, 10.5, 14.1, 6″- or 4″-H), 2.98 (1 H, dddd, *J* 2.3, 6.1, 8.8, 16.5, 4‴-H), 2.86 (1 H, dddd, *J* 2.3, 6.0, 8.7, 16.5, 4‴-H), 2.61 (1 H, ddd, *J* 3.1, 6.2, 14.1, 4″- or 6″-H), 2.56 (1 H, ddd, *J* 3.3, 5.9, 14.0, 6″- or 4″-H), 2.18 (1 H, dd, *J* 4.6, 15.1, 1‴-H), 2.02–1.94 (1 H, m, 5″-H), 1.96 (1 H, dd, *J* 3.9, 15.1, 1‴-H), 1.88–1.78 (1 H, m, 5″-H) and 0.47 (6 H, s, 2 × Me); *m/z* (EI) 551 (M^+ − Me, 0.1%), 534 (M^+ − MeOH, 0.1), 491 [M^+ − $CH(OMe)_2$, 0.1], 477 [M^+ − $CH_2CH(OMe)_2$, 0.2], 359 [M^+ − $(C_3H_6S_2)CCH_2CH(OMe)_2$, 0.2], 317 ($M^+$ − $C_{13}H_{17}O_3Si$, 0.3), 233 ($C_{13}H_{17}O_2Si^+$, 12.6), 207 [$(C_3H_6S_2)CCH_2CH(OMe)_2^+$, 86], 135 ($PhMe_2Si^+$, 20), 89 [$CH_2CH(OMe)_2^+$, 51] and 75 [$CH(OMe)_2^+$, 100] (Found: C, 57.0; H, 6.70. $C_{27}H_{38}O_7S_2Si$ requires C, 57.2; H, 6.8%); and the *more polar isomer* **13** (6.53 g, 34%) as a viscous oil; ν_{max}(film)/cm^{-1} 3065w, 3045w, 2949m, 2829m, 1757s, 1716s, 1676m, 1609w, 1427m, 1377m, 1225s, 1191s, 1116s, 1071s, 1030s, 836s, 785m, 735m and 703m; δ_H(500 MHz) 7.54–7.46 (2 H, m, Ph), 7.41–7.31 (3 H, m, Ph), 7.19 (1 H, s, 3-H), 6.81 (1 H, dt, *J* 9.1, 2.9, 2′-H), 4.72 (1 H, t, *J* 4.5, 2‴-H), 4.33 (1 H, d, *J* 9.1, 1′-H), 4.37–4.29 (1 H, m, 5‴-H), 4.26 (1 H, dt, *J* 6.1, 8.9, 5‴-H), 4.08 (1 H, d, *J* 10.4, allylic CH_2O), 4.02 (1 H, d, *J* 10.4, allylic CH_2O), 3.76 (3 H, s, CO_2Me), 3.33 (3 H, s, OMe), 3.30 (3 H, s, OMe), 3.01–2.85 (3 H, m, 4″-, 6″- and 4‴-H), 2.78 (1 H, dddd, *J* 3.0, 5.5, 8.8, 17.2, 4‴-H), 2.69 (1 H, ddd, *J* 3.6, 7.1, 13.9, 4″- or 6″-H), 2.63 (1 H, ddd, *J* 3.5, 7.0, 14.0, 6″- or 4″-H), 2.18 (1 H, dd, *J* 4.3, 14.9, 1‴-H), 2.01 (1 H, dd, *J* 4.7, 14.9, 1‴-H), 1.98–1.82 (2 H, m, 5″-H_2), 0.48 (3 H, s, Me) and 0.47 (3 H, s, Me); *m/z* (EI, 20 eV) 566 (M^+, <0.1%), 551 (M^+ − Me, 0.3), 534 (M^+ − MeOH, 0.1), 519 (M^+ −0.1), CH_2SH, 489 (M^+ − Ph, 1), 477 [M^+ −$CH_2CH(OMe)_2$, 0.2], 359 [M^+ − $(C_3H_6S_2)CCH_2CH(OMe)_2$, 0.4], 233 ($C_{13}H_{17}O_2Si^+$, 1.1), 207 [$(C_3H_6S_2)CCH_2CH(OMe)_2^+$, 63] and 75 [$CH(OMe)_2^+$, 100] (Found: C, 57.15; H, 6.8%).

(1R*,3aR*,4R*,8bR*)-*Methyl* 1-[2′-(2″,2″-*Dimethoxyethyl*)-1′,3′-*dithian*-2′-*yl*]-4-*dimethyl*(*phenyl*)*silyl*-1,4,5,7,8,8b-*hexahydro*-3H-*benzo*[1,2-b:3,4-c′]*difuran*-3a-*carboxylate* **16** *and its* C-3a, C-4 *Epimer* **17**.—A solution of the lactone **13** (2.25 g, 3.97 mmol) and pyridine (290 mm^3, 3.59 mmol) in toluene–THF (1.8:1; 9.8 cm^3) under argon was cooled to −50 °C and a solution of freshly prepared Tebbe reagent (8.9 cm^3 of a 0.59 mol dm^{-3} solution in toluene, 5.25 mmol) was added dropwise *via* syringe during 35 min. The dark red solution was stirred at −50 °C for 20 min, then was allowed to warm slowly to −35 °C during 1.75 h. The reaction was quenched by addition of DIPEA (1 cm^3, 5.74 mmol), followed by saturated aq. Na_2CO_3 (1.9 cm^3). The cooling bath was removed and the mixture was stirred vigorously for 12 min with occasional cooling to maintain the temperature below 25 °C. The orange suspension was diluted with diethyl ether (35 cm^3) and the mixture was stirred for a further 10 min whereupon it was passed through a short pad of Na_2SO_4 (0.7 × 2 cm) under argon, and the filter was washed thoroughly with anhydrous diethyl ether. The solvent was evaporated under reduced pressure at room temperature and residual toluene was removed under high vacuum (0.02 mmHg) for 5 min. Anhydrous toluene (freshly distilled from sodium under argon; 20 cm^3) was added to the black residue of impure exocyclic alkene **15** under argon, followed by hydroquinone (40 mg, 0.36 mmol) and DIPEA (0.3 cm^3, 1.72 mmol) and the mixture was heated to 85 °C for 4 h. After cooling, the mixture was filtered under suction, and the remaining red solid was washed copiously with diethyl ether. The filtrate was evaporated under reduced pressure and the residue was purified by flash chromatography (gradient elution, 20–40% ethyl acetate–light petroleum) to obtain, in order of elution, the *tricycle* **17** [190 mg, 8%, after purification by column chromatography (35% diethyl ether–light petroleum)] as a pale yellow foam; ν_{max}(film)/cm^{-1} 3066w, 3045w, 2946s, 2858s, 1726, 1674w, 1427m, 1381m, 1284m, 1249m, 1224s, 1204s, 1118s, 1074s, 845m, 821m, 737m and 703m; δ_H(500 MHz; C_6D_6) 7.44–7.37 (2 H, m, Ph), 7.20–7.13 (3 H, m, Ph), 5.22 (1 H, t, *J* 3.8, 2″-H), 4.57 (1 H, d, *J* 8.8, 3-H_α), 4.05 (1 H, d, *J* 4.4, 1-H), 4.05–3.96 (2 H, m, 7-H_2), 3.65 (1 H, br d, *J* 3.3, 8b-H), 3.37 (3 H, s, OMe), 3.34 (3 H, s, OMe), 3.29 (3 H, s, OMe), 3.40–3.15 (2 H, m, 4′- and 6′-H_{ac}), 3.19 (1 H, d, *J* 8.8, 3-H_β), 2.47–2.38 (2 H, m, 4′- or 6′-H_{eq} and 8-H), 2.36–2.25 (2 H, m, 6′- or 4′-H_{eq} and 8-H), 2.33 (1 H, dd, *J* 4.2, 14.8, 1″-H), 2.17 (1 H, dd, *J* 3.4, 14.8, 1″-H), 2.20–2.14 (1 H, m, 5-H_α), 1.99–1.93 (1 H, m, 4-H), 1.91 (1 H, tq, *J* 13.1, 2.7 5-H_β), 1.71–1.57 (2 H, m, 5′-H_2), 0.19 (3 H, s, Me) and 0.17 (3 H, s, Me); δ_C(125.8 MHz; C_6D_6) 175.55 (1 C, s, CO_2Me), 151.99 (1 C, s, C-5a), 137.42 (1 C, s, C-1_{Ph}), 134.48 (2 C, d, C-2, -6_{Ph}), 129.38 (1 C, d, C-4_{Ph}), 128.30 (2 C, d, C-3, -5_{Ph}), 105.31 (1 C, s, C-8a), 103.55 (1 C, d, C-2″), 97.13 (1 C, d, C-1), 68.66 (1 C, t, C-7), 68.50 (1 C, t, C-3), 56.99 and 52.58 (2 C, s, C-3a and -2′), 53.42 (1 C, q, OMe), 52.93 (1 C, q, OMe), 51.56 (1 C, q, OMe), 47.60 (1 C, d, H-8b), 42.79 (1 C, t, C-1″), 33.37 (1 C, t, C-8), 27.97 (2 C, t, C-4′, -6′), 26.88 (1 C, d, C-4), 24.92 (1 C, t, C-5′), 22.18 (1 C, t, C-5), −3.10 (1 C, q, Me) and −3.19 (1 C, q, Me); *m/z* (EI) 564 (M^+, 1.5%), 532 (M^+ − MeOH, 4.1), 489 [M^+ − $CH(OMe)_2$, 0.2], 475 [M^+ − $CH_2CH(OMe)_2$, 0.9], 357 [M^+ − $(C_3H_6S_2)CCH_2CH(OMe)_2$, 13], 207 [$(C_3H_6S_2)$-$CCH_2CH(OMe)_2^+$, 29], 135 ($PhMe_2Si^+$, 36) and 75 [$CH(OMe)_2^+$, 100] (Found: M^+, 564.2030. $C_{28}H_{40}O_6S_2Si$ requires M, 564.2036); the *tricycle* **16** (464 mg, 21%) as a foam; ν_{max}(film)/cm^{-1} 3060w, 3040w, 2948s, 2922s, 2898m, 1736s, 1716m, 1675w, 1428m, 1251m, 1224m, 1195s, 1115s, 1068m, 1026m, 990m, 823m, 781m, 738m and 702m; δ_H(500 MHz; C_6D_6) 7.60–7.51 (2 H, m, Ph), 7.25–7.14 (3 H, m, Ph), 5.18 (1 H, t, *J* 4.1, 2″-H), 5.15 (1 H, d, *J* 9.1, 1-H), 4.12 (2 H, m, 7-H_2), 3.98 (1 H, d, *J* 8.4, 3-H_α), 3.92 (1 H, d, *J* 8.4, 3-H_β), 3.72 (1 H, br d, *J* 7.9, 8b-H), 3.37 (3 H, s, OMe), 3.35 (3 H, s, OMe), 3.32 (3 H, s, OMe), 2.96 (1 H, dt, *J* 13.5, 6.1, 4′- or 6′-H), 2.89 (1 H, m, 8-H), 2.73 (1 H, m, 8-H), 2.56 (1 H, dd, *J* 4.6, 14.8, 1″-H), 2.44 (1 H, d, *J* 7.9, 4-H), 2.39 (1 H, dd, *J* 3.6, 14.8, 1″-H), 2.63–2.33 (5 H, m, 5-H_2, 4′- and 6′-H and 6′- or 4′-H), 1.58 (2 H, quint, *J* 5.8, 5′-H_2), 0.55 (3 H, s, Me) and 0.38 (3 H, s, Me); *m/z* (EI) 564 (M^+, 0.5%), 532 (M^+ − MeOH, 0.8), 489 [M^+ − $CH(OMe)_2$, 0.2], 475 [M^+ − $CH_2CH(OMe)_2$, 0.2], 357 [M^+ − $(C_3H_6S_2)CCH_2CH(OMe)_2$, 4.6], 223 (3.6), 207 [$(C_3H_6S_2)CCH_2CH(OMe)_2^+$, 3.6], 135 ($PhMe_2Si^+$, 38) and 75 [$CH(OMe)_2^+$, 38) and 75 [$CH(OMe)_2^+$, 100] (Found: M^+, 564.2023); and the starting lactone **13** (510 mg, 23% recovery).

(2aR*,3R*,4aR*,7aS*,8S*,10aR*,10bR*)-*Methyl*3-*Dimethyl*-(*phenyl*)*silyl*-4a,8-*dihydroxyperhydronaphtho*[1,8-bc:5,4a-b′]-*difuran*-10-*spiro*-2′-(1′,3′-*dithiane*)-2a-*carboxylate* **18**, *its* C-8 *Epimer* **20** *and* (2aR*,3R*,4aR*,7aS*,8S*,10aR*,10bR*)-*Methyl* 3-*Dimethyl*(*phenyl*)*silyl*-8-*hydroxy*-4a-*methoxyperhydronaphtho*[1,8-bc:5,4a-b′]*difuran*-10-*spiro*-2′-(1′,3′-*dithiane*)-2a-*carboxylate* **19**.—PTSA monohydrate (61 mg, 0.32 mmol) was added to a solution of the tricycle **16** (1.132 g, 2.0 mmol) in 0.5% water–acetonitrile (44 cm^3). The solution was stirred at 55 °C for 5.5 h, then allowed to cool to room temperature and water (1.9 cm^3) was added. The mixture was stirred for 1 h before further water (0.6 cm^3) was added. After a further 1 h, the solution was poured into saturated aq. $NaHCO_3$ (40 cm^3) and extracted with diethyl ether (3 × 100 cm^3). The combined ethereal layers were washed with brine (60 cm^3), the brine was re-extracted with diethyl ether (60 cm^3), and the combined organic layers were dried ($MgSO_4$). After evaporation of the solvent under reduced pressure, the residue was purified twice by flash chromatography (50% diethyl ether–light petroleum) to obtain, in order of elution, the *methyl ketal* **19** (110 mg, 10%) as a foam; ν_{max}(film)/cm^{-1} 3508m, 2951m, 2918m, 2883m,

1724s, 1425m, 1256m, 1203s, 1113m, 1077s, 1046s, 733m and 701m; δ_H(500 MHz) 7.58–7.52 (2 H, m, Ph), 7.39–7.31 (3 H, m, Ph), 4.36 (1 H, d, *J* 11.4, 10a-H), 3.99 (1 H, ddd, *J* 1.0, 3.9, 11.5, 8-H), 3.94 (1 H, d, *J* 8.6, 2-H), 3.73 (3 H, s, CO_2Me), 3.79–3.64 (2 H, m, 6-H_2), 3.57 (1 H, d, *J* 8.7, 2-H), 3.53 (1 H, d, *J* 1.2, 8-OH), 3.32 (1 H, ddd, *J* 2.6, 11.0, 13.9, 4′- or 6′-H), 3.22 (1 H, ddd, *J* 3.0, 11.3, 13.6, 6′- or 4′-H), 3.20 (3 H, s, OMe), 2.71–2.65 (1 H, m, 4′- or 6′-H), 2.66 (1 H, d, *J* 11.4, 10b-H), 2.56 (1 H, dd, *J* 6.4, 12.8, 3-H), 2.60–2.52 (1 H, m, 6′- or 4′-H), 2.22 (1 H, dd, *J* 3.9, 14.2, 9-H_{eq}), 2.25–2.15 (2 H, m, 4- and 7-H), 2.13–2.05 (1 H, m, 5′-H), 2.01 (1 H, dt, *J* 12.8, 9.1, 7-H), 1.98–1.88 (1 H, m, 5′-H), 1.64 (1 H, t, *J* 13.4, 4-H), 1.59 (1 H, dd, *J* 11.3, 13.9, 9-H_{ax}), 0.42 (3 H, s, Me) and 0.34 (3 H, s, Me); *m/z* (EI, 20 eV) 550 (M^+, 4.3%), 535 (M^+ – Me, 4.4), 5.19 (M^+ – OMe, 4.4), 518 (M^+ – MeOH, 4.7), 503 (M^+ – CH_2SH, 2.1), 491 (M^+ – OMe – CO, 1.6), 473 (M^+ – Ph, 1), 415 (M^+ – $PhMe_2Si$, 15.9), 388 (21), 357 (35) and 135 ($PhMe_2Si^+$, 100) (Found: M^+, 550.1889. $C_{27}H_{38}O_6S_2Si$ requires M, 550.1879); the *hemiketal* **18** (484 mg, 45%) as crystals; m.p. 194 °C (from diethyl ether–light petroleum); ν_{max}(film)/cm^{-1} 3360m, 3070w, 3049w, 2952s, 2926m, 1725s, 1425m, 1203s, 1114m, 1076m, 1049s, 844m, 821m, 735m and 702m; δ_H(500 MHz) 7.57–7.50 (2 H, m, Ph), 7.37–7.30 (3 H, m, Ph), 4.35 (1 H, d, *J* 11.5, 10a-H), 4.03 (1 H, ddd, *J* 1.6, 3.9, 11.5, 8-H), 3.95 (1 H, d, *J* 8.5, 2-H), 3.85 (1 H, q, *J* 8.6, 6-H), 3.75 [1 H, m, (obscured by OMe), 6-H], 3.73 (3 H, s, CO_2Me), 3.64 (1 H, d, *J* 8.5, 2-H), 3.33 (1 H, ddd, *J* 2.6, 11.0, 14.0, 4′- or 6′-H), 3.30 (1 H, d, *J* 1.7, 8-OH), 3.25 (1 H, ddd, *J* 3.0, 11.3, 13.6, 6′- or 4′-H), 2.69 (1 H, s, 4a-OH), 2.68 [1 H, d, *J* 11.5 (obscured by OH; coupling constant was determined after D_2O exchange), 10b-H], 2.72–2.65 (1 H, m, 4′- or 6′-H), 2.63 (1 H, dd, *J* 6.4, 12.8, 3-H), 2.56 (1 H, br dt, *J* 13.9, 4.4, 6′- or 4′-H), 2.23 (1 H, dd, *J* 3.9, 14.2, 9-H), 2.22 (1 H, dt, *J* 3.2, 10.8, 7-H), 2.14–2.05 (1 H, m, 5′-H), 2.05–1.89 (2 H, m, 7- and 5′-H), 1.96 (1 H, br, t, *J* 13.4, 4-H), 1.81 (1 H, dd, *J* 6.4, 14.1, 4-H), 1.62 (1 H, dd, *J* 11.5, 14.2, 9-H), 0.39 (3 H, s, Me) and 0.35 (3 H, s, Me); *m/z* (EI) 536 (M^+, 12%), 518 (M^+ – H_2O, 8), 504 (M^+ – MeOH, 7.8), 489 (M^+ – CH_2SH, 0.4), 477 (M^+ – OMe – CO, 0.6), 459 (M^+ – Ph, 5), 357 (9.1), 325 (4.7), 297 (4.9), 265 (2) and 135 ($PhMe_2Si^+$, 100) (Found: M^+, 536.1736; C, 58.2; H, 6.8%. $C_{26}H_{36}O_6S_2Si$ requires M, 536.1723; C, 58.2; H, 6.8%); and the *hemiketal* **20** (84 mg, 8%) as short needles; m.p. 185 °C (from diethyl ether–light petroleum); ν_{max}(film)/cm^{-1} 3392m, 3045w, 2948m, 2921m, 2892m, 1722s, 1424m, 1249m, 1203s, 1154m, 1108s, 1056s, 991m, 845m, 734m and 701m; δ_H(500 MHz) 7.58–7.52 (2 H, m, Ph), 7.36–7.30 (3 H, m, Ph), 4.35 (1 H, d, *J* 11.6, 10a-H), 4.00 (1 H, d, *J* 8.5, 2-H), 3.98–3.89 (2 H, m, 6- and 8-H), 3.71 (3 H, s, CO_2Me), 3.77–3.69 (1 H, m, 6-H), 3.66 (1 H, d, *J* 8.5, 2-H), 3.55 (1 H, br d, *J* 4.8, 8-OH), 3.29 (1 H, dt, *J* 13.6, 3.4, 4′- or 6′-H), 3.27 (1 H, dt, *J* 13.9, 3.3, 6′- or 4′-H), 3.19 (1 H, d, *J* 11.6, 10b-H), 2.89 (1 H, br s, 4a-OH), 2.76 (1 H, ddd, *J* 2.9, 6.7, 13.9, 4′- or 6′-H), 2.62 (1 H, ddd, *J* 3.2, 6.2, 13.7, 6′- or 4′-H), 2.59 (1 H, dd, *J* 6.6, 12.3, 3-H), 2.46 (1 H, dd, *J* 2.4, 15.4, 9-H), 2.3 (1 H, br dt, *J* 12.5, 9.0, 7-H), 2.11–2.03 (1 H, m, 5′-H), 1.99 (1 H, br t, *J* 13.1, 4-H), 1.83 (1 H, dd, *J* 6.6, 14.0, 4-H), 1.73 (1 H, dd, *J* 3.1, 15.4, 9-H), 1.39 (1 H, ddd, *J* 3.1, 8.7, 12.9, 7-H), 0.42 (3 H, s, Me) and 0.36 (3 H, s, Me); δ_C(125.8 MHz) 175.6 (1 C, s, CO_2Me), 137.9 (1 C, s, C-1_{Ph}), 133.9 (2 C, d, C-2,6_{Ph}), 129.2 (1 C, d, C-4_{Ph}), 127.9 (2 C, d, C-3,-5_{Ph}), 107.1 (1 C, s, C-4a), 88.1 (1 C, d, C-10a), 77.3 (1 C, t, C-2), 74.5 (1 C, d, C-8), 65.0 (1 C, t, C-6), 53.2, 51.5 and 49.9 (3 C, s, C-7a, -2a and -10), 52.2 (1 C, q, OMe), 46.2 (1 C, d, C-10b), 41.6 (1 C, t, C-9), 36.0 (1 C, t, C-4), 29.9 (1 C, t, C-7), 27.7 (1 C, t, C-4′ or -6′), 27.7 (1 C, t, C-6′ or -4′), 25.1 (1 C, t C-5′), 22.3 (1 C, d, C-3), –2.5 (1 C, q, Me) and –3.0 (1 C, q, Me); *m/z* (EI) 536 (M^+, 1.8%), 521 (M^+ – Me, 0.5), 518 (M^+ – H_2O, 0.9), 504 (M^+ – MeOH, 1.8), 476 (M^+ – MeOH – CO, 0.5), 459 (M^+ – Ph, 1.9), 428 (0.9), 374 (3.9), 357 (7.7), 161 (17) and 135 ($PhMe_2Si^+$, 100) (Found: C, 58.2; H, 6.8%).

(2aR*,3R*,4aR*,7aS*,8S*,10aR*,10bR*)-*Methyl* 3-*Dimethyl*(*phenyl*)*silyl*-4a,8-*dihydroxyperhydronaphtho*[1,8-bc:5,4a-b′]*difuran*-10-*spiro*-2′-(1′,3′-*dithiane*)-2a-*carboxylate* **18** *by Hydrolysis of the Methyl Ketal* **19**.—The methyl ketal **19** (410 mg, 0.75 mmol) was dissolved in acetonitrile (25 cm^3). Water (125 mm^3) was added, followed by PTSA monohydrate (33 mg, 0.17 mmol) and the solution was stirred at 53 °C for 4.75 h. After the mixture had cooled, further water (1 cm^3) was added and again (0.3 cm^3) after 30 min. The solution was stirred for a further 1 h, then poured into saturated aq. $NaHCO_3$ (20 cm^3) and extracted with diethyl ether (3 × 50 cm^3). The combined ether layers were washed with brine (30 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. Purification of the residue by flash chromatography (50% diethyl ether–light petroleum) furnished the hemiketal **18** (235 mg, 59%) as crystals, spectroscopically identical with the previously prepared material.

(2aR*,3R*,5aS*,6S*,8aR*,8bR*)-*Methyl* 3-*Dimethyl*(*phenyl*)*silyl*-5-*oxo*-6-*pivaloyloxy*-5a-(2″-*pivaloyloxyethyl*)*perhydronaphtho*[1,8-bc]*furan*-8-*spiro*-2′-(1′,3′-*dithiane*)-2a-*carboxylate* **21**.—Pivaloyl chloride (6 cm^3, 48.7 mmol) was added to a stirred solution of the hemiketal **18** (1.725 g, 3.21 mmol) and DMAP (1 g, 8.18 mmol) in pyridine (4.8 cm^3, 59.3 mmol)–CH_2Cl_2 (25 cm^3). The reaction mixture was heated to 45 °C for 72 h, then poured into saturated aq. $NaHCO_3$ (100 cm^3) and the aqueous layer was re-extracted with CH_2Cl_2 (4 × 100 cm^3). The combined organic layers were dried ($MgSO_4$) and evaporated under reduced pressure. Flash chromatography (gradient elution: 10–35% diethyl ether–light petroleum) of the residue gave a solid, which was recrystallized to purity from diethyl ether–light petroleum to obtain the *ketone* **21** (1.84 g, 81%) as crystals; m.p. 179 °C; ν_{max}(film)/cm^{-1} 3067w, 2966s, 1716s, 1588w, 1479m, 1427m, 1280m, 1209m, 1155s, 1072m, 1042m, 911m, 819m, 780m, 734s and 703m; δ_H(500 MHz) 7.48–7.42 (2 H, m, Ph), 7.39–7.31 (3 H, m, Ph), 5.22 (1 H, dd, *J* 3.8, 11.9, 6-H), 4.55 (1 H, d, *J* 11.5, 8a-H), 4.32 (1 H, ddd, *J* 6.1, 8.9, 11.1, 2″-H), 3.92 (1 H, ddd, *J* 5.7, 9.2, 11.1, 2″-H), 3.83 (3 H, s, CO_2Me), 3.82 (1 H, d, *J* 9.0, 2-H), 3.66 (1 H, d, *J* 9.0, 2-H), 3.21 (1 H, dd, *J* 8.7, 14.9, 4-H), 3.13 (1 H, ddd, *J* 2.9, 8.9, 14.0, 4′- or 6′-H), 3.04 (1 H, ddd, *J* 3.2, 9.1, 13.9, 6′- or 4′-H), 2.87 (1 H, d, *J* 11.5, 8b-H), 2.80 (1 H, ddd, *J* 3.0, 7.5, 13.9, 4′- or 6′-H), 2.71 (1 H, ddd, *J* 3.2, 7.2, 13.8, 6′- or 4′-H), 2.68 (1 H, br d, *J* 7.6, 3-H), 2.45 (1 H, dd, *J* 1.5, 14.9, 4-H), 2.40 (1 H, dd, *J* 3.8, 14.0, 7-H), 2.16 (1 H, ddd, *J* 6.1, 9.2, 14.8, 1″-H), 2.07–1.87 (3 H, m, 5′-H_2 and 1″-H), 1.75 (1 H, dd, *J* 11.9, 14.0, 7-H), 1.20 (9 H, s, Bu^t), 1.16 (9 H, s, Bu^t), 0.46 (3 H, s, Me) and 0.36 (3 H, s, Me); δ_C(125.8 MHz; 2 quaternary carbons not detected) 210.0 (1 C, s, C-5), 178.2, 177.1 and 175.3 (3 C, s, CO_2R), 137.2 (1 C, s, C-1_{Ph}), 133.5 and 128.3 (4 C, d, C-2,-6_{Ph} and C-3,-5_{Ph}), 129.6 (1 C, d, C-4_{Ph}), 84.9 (1 C, d, C-6), 76.4 (1 C, t, C-2″), 70.5 (1 C, d, C-8a), 61.5 (1 C, t, C-2), 53.6 (1 C, s), 53.3 (1 C, d, C-8b), 52.7 (1 C, q, OMe), 51.6 and 51.1 (2 C, s), 38.6 and 37.7 (2 C, t, C-4′ and -6′), 29.6 (1 C, d, C-3), 27.3, 26.8, 25.8, 25.3 (4 C, t, C-4, -7, -5′, -1″), 27.12 and 27.07 (6 C, q, 2 × Bu^t), –1.6 (1 C, q, Me) and –2.2 (1 C, q, Me); *m/z* (EI) 704 (M^+, 17%), 789 (M^+ – Me, 0.3), 673 (M^+ – OMe, 0.3), 645 (M^+ – CO – OMe, 0.4), 619 (M^+ – Bu^t – CO, 0.7), 603 (M^+ – Bu$^t CO_2$, 4.8), 543 (3.9), 517 (1.3), 501 (1.8), 135 ($PhMe_2Si^+$, 64) and 57 (Bu^{t+}, 100) (Found: M^+, 704.2892; C, 61.3; H, 7.5%. $C_{36}H_{52}O_8S_2Si$ requires M, 704.2873; C, 61.3; H, 7.4%).

(2aR*,3R*,5S*,5aR*,6S*,8aR*,8bR*)-*Methyl* 3-*Dimethyl*(*phenyl*)*silyl*-5-*hydroxy*-6-*pivaloyloxy*-5a-(2″-*pivaloyloxyethyl*)-*perhydronaphtho*[1,8-bc]*furan*-8-*spiro*-2′-(1′,3′-*dithiane*)-2a-*carboxylate* **22** *and* (2aR*,3R*,5S*,5aR*,6S*,8aR*,8bR*)-*Methyl* 3-*Dimethyl*(*phenyl*)*silyl*-5,6-*dihydroxy*-5a-(2″-*pivaloyloxyethyl*)*perhydronaphtho*[1,8-bc]*furan*-8-*spiro*-2′-(1′,3′-*dithiane*)-

2a-*carboxylate* **23**.—Methanol (55 cm^3) was added to a stirred solution of the ketone **21** (950 mg, 1.347 mmol) in anhydrous THF (28 cm^3), followed by sodium borohydride (100 mg, 2.64 mmol). After 15 min, further sodium borohydride (15 mg, 0.4 mmol) was added and again after 50 min. Excess of borohydride was destroyed after a total of 90 min by addition of Amberlyst® 15 ion-exchange resin (~600 mg) and the mixture was vigorously stirred until effervescence had ceased. The mixture was then filtered, the filter was washed with ethyl acetate, and the filtrate was evaporated under reduced pressure. Purification of the residue by flash chromatography (gradient elution, 30–75% diethyl ether–light petroleum) afforded, in order of elution, the *alcohol* **22** (780 mg, 82%) as a foam; ν_{max}(film)/cm^{-1} 3467m, 3068w, 3045w, 2969m, 1722s, 1478m, 1281m, 1205m, 1163s, 1037m, 815m, 779m, 735m and 701m; δ_H(500 MHz) 7.57–7.51 (2 H, m, Ph), 7.36–7.28 (3 H, m, Ph), 5.37 (1 H, dd, *J* 5.0, 11.3, 6-H), 4.61 (1 H, d, *J* 12.0, 8a-H), 4.17 (1 H, dt, *J* 6.1, 10.5, 2″-H), 4.00 [1 H, d, *J* 9.0 (partially obscured by OH; the coupling constant was determined after D_2O exchange), 2-H], 3.99 (1 H, br s, OH), 3.98 [1 H, dt, *J* 4.9, 10.7 (partially obscured by OH; the coupling constant was determined after D_2O exchange), 2″-H], 3.73 (3 H, s, CO_2Me), 3.70 [1 H, m, (changes to t, *J* 2.8 on D_2O exchange), 5-H], 3.64 (1 H, d, *J* 9.0, 2-H), 3.39 (1 H, ddd, *J* 2.6, 10.7, 13.8, 4′- or 6′-H_{ax}), 3.32 (1 H, ddd, *J* 2.9, 10.9, 13.7, 6′- or 4′-H_{ax}), 2.91 (1 H, d, *J* 12.0, 8b-H), 2.74 (1 H, ddd, *J* 2.8, 6.0, 13.8, 4′- or 6′-H), 2.64 (1 H, ddd, *J* 3.3, 5.4, 13.6, 6′- or 4′-H_{eq}), 2.41 (1 H, dd, *J* 1.6, 6.3, 3-H), 2.18–1.89 (7 H, m, 4-, 7-, 5′-H_2 and 1″-H), 1.42 (1 H, ddd, *J* 4.9, 10.5, 14.7, 1″-H), 1.21 (9 H, s, Bu^t), 1.17 (9 H, s, Bu^t), 0.59 (3 H, s, Me) and 0.41 (3 H, s, Me); *m/z* (EI) 706 (M^+, 1.2%), 691 (M^+ − Me, 0.1), 675 (M^+ − OMe, 0.2), 647 (M^+ − OMe − CO, 0.1), 628 (M^+ − OMe − CO − H_2O, 1.7), 604 (M^+ − Bu^tCO_2H, 0.5), 545 (0.4), 527 (1.6), 467 (1.1), 279 (3.2), 135 ($PhMe_2Si^+$, 42) and 57 (Bu^{t+}, 100) (Found: M^+, 706.3033; C, 61.2; H, 7.9%. $C_{36}H_{54}O_8S_2Si$ requires M, 706.3029; C, 61.2; H, 7.7%); and the *diol* **23** (120 mg, 14%) as crystals; m.p. 192–193 °C (from Et_2O–light petroleum); ν_{max}(film)/cm^{-1} 3498m, 3064w, 3040w, 2951m, 1718s, 1478m, 1425m, 1284m, 1206m, 1173s, 1067s, 909m, 815m and 733m; δ_H(500 MHz) 7.55–7.46 (2 H, m, Ph), 7.38–7.30 (3 H, s, Ph), 4.45 (1 H, d, *J* 11.8, 8a-H), 4.42–4.33 (2 H, m, 2″- and 6-H), 4.23 (1 H, dt, *J* 4.9, 10.6, 2″-H), 4.13 (1 H, dt, *J* 6.4, 3.6, 5-H), 3.93 (1 H, d, 2-H_α), 3.71 (3 H, s, CO_2Me), 3.67 (1 H, d, *J* 8.7, 2-H_β), 3.36 (1 H, dd, *J* 2.6, 10.9, 13.9, 4′- or 6′-H_{ax}), 3.29 (1 H, ddd, *J* 3.0, 11.1, 13.5, 6′- or 4′-H_{ax}), 2.74 (1 H, d, *J* 11.8, 8b-H), 2.78–2.68 (1 H, m, 4′- or 6′-H_{eq}), 2.65 (1 H, d, *J* 4.8, 6-OH), 2.60 (1 H, dt, *J* 13.7, 4.4, 6′- or 4′-H_{eq}), 2.50 (1 H, t, *J* 6.3, 3-H), 2.22 (1 H, dd, *J* 3.9, 14.1, 7-H), 2.15–2.06 (1 H, m, 5′-H), 2.01 (1 H, d, *J* 3.6, 5-OH), 2.04–1.84 (5 H, m, 4-H_2, 7-, 5′- and 1″-H), 1.32–1.22 (1 H, m, 1″-H), 1.17 (9 H, s, Bu^t), 0.47 (3 H, s, Me) and 0.41 (3 H, s, Me); *m/z* (EI) 622 (M^+, 0.1%), 520 (M^+ − Bu^tCO_2H, 4.2), 502 (M^+ − Bu^tCO_2H − H_2O, 0.6), 461 (M^+ − Bu^tCO_2H − OMe − CO, 0.9), 442 (10), 227 (16), 199 (17), 135 ($PhMe_2Si^+$, 67) and 57 (Bu^{t+}, 100) (Found: M^+ − Bu^tCO_2H, 520.1774. $C_{26}H_{36}O_5S_2Si$ requires *m/z*, 520.1773) (Found: C, 60.0; H, 7.6. $C_{31}H_{46}O_7S_2Si$ requires C, 59.8; H, 7.4%).

(2a*R**,3*R**,5*S**,5a*R**,6*S**,8a*R**,8b*R**)-*Methyl* 3-*Dimethyl*(*phenyl*)*silyl*-5-*hydroxy*-8-*oxo*-6-*pivaloyloxy*-5a-(2′-*pivaloyloxyethyl*)*perhydronaphtho*[1,8-bc]*furan*-2a-*carboxylate* **24**.—Methyl iodide (700 mm^3, 11.2 mmol) was added to a stirred suspension of the dithiane **22** (780 mg, 1.1 mmol) and calcium carbonate (1.2 g, 12 mmol) in acetonitrile–water (1:1; 40 cm^3). The mixture was heated to reflux (oil-bath temperature 55 °C) and further methyl iodide (200 mm^3, 3.21 mmol) was added after 1 h. After 3 h, further methyl iodide (400 mm^3, 6.43 mmol) was introduced and again (200 mm^3, 3.21 mmol) after 6 h. The mixture was heated for a further 1 h, then allowed to cool and the volatiles were evaporated off under reduced pressure. After removal of residual water under high vacuum (0.02 mmHg), the residue was extracted exhaustively with small portions of CH_2Cl_2 and ethyl acetate. The solvent was evaporated off and the residue was filtered through a short pad of silica, with 90% diethyl ether–light petroleum as eluent, to obtain the *ketone* **24** (669 mg, 98%) as a foam which could be recrystallized from CH_2Cl_2 or diethyl ether–light petroleum; m.p. 165 °C; ν_{max}(film)/cm^{-1} 3468m, 3067w, 3045w, 2970s, 2903m, 1722s, 1585w, 1479m, 1459, 1282m, 1205m, 1159s, 1074m, 1033m, 912m, 830m, 814m, 733s and 702m; δ_H(500 MHz) 7.52–7.45 (2 H, m, Ph), 7.34–7.27 (3 H, m, Ph), 5.26 (1 H, dd, *J* 5.0, 12.6, 6-H), 4.92 [1 H, dd, *J* 0.8 (long-range coupling to 7-H_β), 14.4, 8a-H], 4.31 (1 H, dt, *J* 5.9, 10.4, 2′-H), 4.11 (1 H, dt, *J* 5.0, 10.6, 2′-H), 4.07 (1 H, dd, *J* 1.7, 4.0, OH), 4.01 (1 H, d, *J* 9.4, 2-H), 3.80 (1 H, dt, *J* 2.8, 3.4, 5-H), 3.73 (3 H, s, CO_2Me), 3.67 (1 H, d, *J* 9.4, 2-H), 2.90 [1 H, dt, *J* 1.0 (long-range coupling to 8a-H), 13.1, 7-H_β], 2.53 (1 H, dd, *J* 5.0, 13.5, 7-H_α), 2.40 (1 H, dd, *J* 1.7, 6.2, 3-H), 2.27 (1 H, d, *J* 14.0, 8b-H), 2.19–2.06 (2 H, m, 1′-H, 4-H_{ax}), 2.01 (1 H, br d, *J* 13.1, 4-H_{eq}), 1.61 (1 H, ddd, *J* 5.0, 10.3, 14.7, 1′-H), 1.22 (9 H, s, Bu^t), 1.18 (9 H, s, Bu^t), 0.47 (3 H, s, Me) and 0.34 (3 H, s, Me); *m/z* (EI) 514 (M^+ − Bu^tCO_2H, 0.3%), 499 (M^+ − Bu^tCO_2H − Me, 1), 437 (M^+ − Bu^tCO_2H − Ph, 1.4), 4.12 (0.4), 380 (0.9), 335 (1.1), 135 ($PhMe_2Si^+$, 100) and 57 (Bu^{t+}, 50) [Found: (CI, NH_3): M + NH_4^+, 634.3411. $C_{33}H_{52}NO_9Si$ requires *m/z* 634.3411. Found: C, 64.1; H, 8.0. $C_{33}H_{48}O_9Si$ requires C, 64.3; H, 7.8%].

(2a*R**,3*R**,5*S**,5a*R**,6*S**,8a*R**,8b*R**)-*Methyl* 6-*Benzyloxy*-3-*dimethyl*(*phenyl*)*silyl*-5-*hydroxy*-5a-(2″-*pivaloyloxyethyl*)*perhydronaphtho*[1,8-bc]*furan*-8-*spiro*-2′-(1′,3′-*dithiane*)-2a-*carboxylate* **25**.—Benzoyl cyanide (84 mg, 0.64 mmol) was added in one portion to a stirred solution of the diol **23** (298 mg, 0.478 mmol) and triethylamine (4.0 cm^3, 28.7 mmol) in CH_2Cl_2–acetonitrile (2:5; 14 cm^3) at 0 °C. After 45 min, water (0.4 cm^3) was added (**CAUTION**: Evolution of HCN!) and the volatiles were evaporated off under reduced pressure. Residual solvent was removed under high vacuum (0.02 mmHg) for 10 min and the resulting yellow residue was purified by flash chromatography (gradient elution, 20–35% diethyl ether–light petroleum) to obtain the *benzoate* **25** (274 mg, 79%) as crystals; m.p. 188 °C (from Et_2O–light petroleum); ν_{max}(film)/cm^{-1} 3468m, 3063w, 2951m, 2900m, 1719s, 1599w, 1582w, 1448m, 1278s, 1206m, 1154s, 1115m, 1069m, 815m, 736m and 713m; δ_H(500 MHz) 8.03 (2 H, dd, *J* 1.3, 8.3, RO_2CPh), 7.61 (1 H, tt, *J* 1.2, 7.5, RO_2CPh), 7.59–7.52 (2 H, m, Ph), 7.48 (2 H, dd, *J* 7.6, 8.1, RO_2CPh), 7.37–7.28 (3 H, m, Ph), 5.68 (1 H, dd, *J* 4.1, 12.1, 6-H), 4.63 (1 H, d, *J* 12.0, 8a-H), 4.25 (1 H, dt, *J* 5.9, 10.2, 2″-H), 4.22 (1 H, dd, *J* 1.8, 3.6, OH), 4.03 (1 H, d, *J* 9.0, 2-H), 3.98 (1 H, dt, *J* 5.4, 10.4, 2″-H), 3.82 (1 H, br d, *J* 2.7, 5-H), 3.73 (3 H, s, OMe), 3.65 (1 H, d, *J* 9.0, 2-H), 3.34 (1 H, ddd, *J* 2.7, 10.0, 13.9, 4′- or 6′-H_{ax}), 3.29 (1 H, ddd, *J* 3.0, 10.1, 13.7, 6′- or 4′-H_{ax}), 2.98 (1 H, d, *J* 12.0, 8b-H), 2.79 (1 H, ddd, *J* 2.9, 6.7, 13.8, 4′- or 6′-H_{eq}), 2.69 (1 H, ddd, *J* 3.3, 6.3, 13.7, 6′- or 4′-H_{eq}), 2.43 (1 H, dd, *J* 1.5, 6.3, 3-H), 2.37 (1 H, dd, *J* 4.2, 13.8, 7-H), 2.27 (1 H, t, *J* 13.0, 7-H), 2.18–1.92 (5 H, m, 4- and 5′-H_2, 1″-H), 1.46 (1 H, ddd, *J* 5.3, 9.7, 14.8, 1″-H), 1.10 (9 H, s, Bu^t), 0.64 (3 H, s, Me) and 0.44 (3 H, s, Me); *m/z* (EI) 726 (M^+, 0.5%), 649 (M^+ − Ph, 0.6), 624 (M^+ − Bu^tCO_2H, 0.4), 604 (M^+ − HO_2CPh, 0.2), 589 (M^+ − HO_2CPh − Me, 0.2), 527 (M^+ − HO_2CPh − Ph, 0.9), 502 (M^+ − Bu^tCO_2H − HO_2CPh, 0.9), 135 ($PhMe_2Si^+$, 69), 105 ($PhCO^+$, 100), 77 (Ph^+, 29) and 57 (Bu^{t+}, 55) (Found: M^+, 726.2716; C, 62.8; H, 7.0%. $C_{38}H_{50}O_8S_2Si$ requires M, 726.2716; C, 62.8; H, 6.9%).

(2a*R**,3*R**,5*S**,5a*R**,6*S**,8a*R**,8b*R**)-*Methyl* 6-*Benzoyloxy*-3-*dimethyl*(*phenyl*)*silyl*-5-*hydroxy*-8-*oxo*-5a-(2′-*pivaloyloxy ethyl*)*perhydronaphtho*[1,8-bc]*furan*-2a-*carboxylate* **26**.—

Methyl iodide (250 mm^3, 4.02 mmol) was added to a stirred suspension of the dithiane **25** (265 mg, 0.364 mmol) and calcium carbonate (400 mg, 4.0 mmol) in acetonitrile–water (1:1; 10 cm^3). The mixture was heated to reflux (oil-bath temperature 55 °C) for 75 min and then further methyl iodide (100 mm^3, 1.61 mmol) was added. After 3.5 h, further methyl iodide (100 mm^3, 1.61 mmol) was introduced and again (120 mm^3, 1.93 mmol) after 6 h. The mixture was heated for a further 1 h, then allowed to cool and the volatiles were evaporated off under reduced pressure. Residual water was removed under high vacuum (0.02 mmHg) before the residue was extracted exhaustively with small portions of CH_2Cl_2 and ethyl acetate. The solvent was evaporated off and the residue was filtered through a short pad of silica, and eluted with 90% diethyl ether–light petroleum to obtain the β-*benzoyloxy ketone* **26** (232 mg, 100%) as a foam; ν_{max}(film)/cm^{-1} 3471m, 3065w, 2955m, 2903m, 1722s, 1600w, 1583w, 1448m, 1280s, 1263s, 1154m, 1071m, 1026m, 824m, 733m and 713m; δ_H(500 MHz) 8.04 (2 H, dd, *J* 1.1, 7.5, RO_2CPh), 7.64 (1 H, tt, *J* 1.1, 7.2, RO_2CPh), 7.55–7.44 (4 H, m, Ph), 7.37–7.28 (3 H, m, Ph), 5.59 (1 H, dd, *J* 5.2, 12.6, 6-H), 4.98 [1 H, dd, *J* 0.5 (long-range coupling to 7-H_β), 13.8, 8a-H], 4.39 (1 H, dt, *J* 6.1, 10.2, 2′-H), 4.22 (1 H, dd, *J* 1.0, 4.2, OH), 4.10 (1 H, dt, *J* 5.5, 10.3, 2′-H), 4.05 (1 H, d, *J* 8.7, 2-H), 3.92 (1 H, dt, *J* 2.6, 4.5, 5-H), 3.75 (3 H, s, CO_2Me), 3.70 (1 H, d, *J* 8.7, 2-H), 3.07 [1 H, dt, *J* 0.5 (long-range coupling to 8a-H), 12.7, 7-H_β), 2.69 (1 H, dd, *J* 5.2, 13.5, 7-H_α), 2.43 (1 H, dd, *J* 1.7, 6.5, 3-H), 2.36 (1 H, d, *J* 13.7, 8b-H), 2.27–2.12 (2 H, m, 1′-H, 4-H_{ax}), 2.05 (1 H, br d, *J* 14.4, 4-H_{eq}), 1.66 (1 H, dd, *J* 5.5, 9.8, 14.2, 1′-H), 1.14 (9 H, s, Bu^t), 0.53 (3 H, s, Me) and 0.39 (3 H, s, Me); *m*/*z* (CI, NH_3) 654 [(M + NH_4)$^+$, 6.6%], 532 [(M + NH_4)$^+$ − HO_2CPh, 100], 515 [(M + NH_4)$^+$ − HO_2CPh − OH, 8.1], 497 (M^+ − HO_2CPh − OH, 7.5), 454 (1.8), 437 (3.5), 419 (3.5), 402 (4), 335 (2), 291 (4.7), 261 (2), 199 (4.9), 152 (8.8) and 105 ($PhCO^+$, 6.5) [Found: (CI, NH_3): M + NH_4^+, 654.3100. $C_{35}H_{48}NO_9Si$ requires *m*/*z*, 654.3098].

(2aR*,3R*,5S*,5aR*,8aR*,8bR*)-*Methyl* 3-*Dimethyl(phenyl)silyl*-5-*hydroxy*-8-*oxo*-5a-(2′-*pivaloyloxyethyl*)-4,5,5a,8,8a,-8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]-*furan*-2a-*carboxylate* **27**.—DBU (0.65 cm^3, 4.35 mmol) was added *via* syringe to a stirred solution of the β-pivaloyloxy ketone **24** (1.20 g, 1.95 mmol) and the β-benzoyloxy ketone **26** (0.24 g, 0.38 mmol) in CH_2Cl_2 (35 cm^3) at room temperature under argon. After 135 min, the solvent was evaporated off under reduced pressure and the residue was purified by flash chromatography (gradient elution, 70–80% diethyl ether–light petroleum) to obtain the *enone* **27** (1.2 g, 100%) as a foam; ν_{max}(film)/cm^{-1} 3484m, 3070w, 3045w, 2954m, 1722s, 1696s, 1590w, 1478m, 1282m, 1215m, 1158s, 1050m, 815m, 735m and 701m; δ_H(500 MHz) 7.52–7.46 (2 H, m, Ph), 7.39–7.30 (3 H, m, Ph), 6.81 (1 H, d, *J* 10.1, 6-H), 6.03 (1 H, d, *J* 10.1, 7-H), 4.67 (1 H, d, *J* 14.3, 8a-H), 4.17 (1 H, br d, *J* 1.9, 5-H), 4.15–4.05 (2 H, m, 2′-H), 4.03 (1 H, d, *J* 9.4, 2-H), 3.82 (1 H, d, *J* 9.4, 2-H), 3.74 (3 H, s, CO_2Me), 2.86 (1 H, d, *J* 14.3, 8b-H), 2.43 (1 H, dd, *J* 1.3, 6.8, 3-H), 2.28 (1 H, ddd, *J* 2.4, 6.8, 15.7, 4-H), 1.93–1.84 (2 H, m, 4- and 1′-H), 1.66 (1 H, dt, *J* 14.3, 6.9, 1′-H), 1.5 (1 H, d, *J* 3.8, OH), 1.17 (9 H, s, Bu^t), 0.42 (3 H, s, Me) and 0.36 (3 H, s, Me); *m*/*z* (EI) 514 (M^+, 0.4%), 499 (M^+ − 0.1), 455 (M^+ − OMe − CO, 0.3), 437 (M^+ − Ph, 0.4), 412 (M^+ − Bu$^t CO_2H$, 0.2), 380 (0.4), 278 (1.6), 135 ($PhMe_2Si^+$, 21) and 57 (Bu^{t+}, 22) (Found: M^+, 514.2391; C, 65.0; H, 7.55%. $C_{28}H_{38}O_7Si$ requires M, 514.2387; C, 65.3; H, 7.4%).

(2aR*,3S*,5R*,5aS*,8aS*,8bS*)-*Methyl* 3,5-*Dihydroxy*-8-*oxo*-5a-(2′-*pivaloyloxyethyl*)-4,5,5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **28**.—Glacial acetic acid (1 cm^3) and TFA (1 cm^3) were added to a mixture of the silane **27** (180 mg, 0.35 mmol) and mercury(II) trifluoroacetate (180 mg, 0.42 mmol). The mixture was stirred for 10 min at room temperature, then was cooled to 10 °C and peracetic acid (225 mm^3 of a 32 wt% solution in dil. acetic acid, 1.07 mmol) was added. After 5 min, the solution was allowed to warm to room temperature and was stirred for a further 2 h whereupon the reaction was quenched by dilution with CH_2Cl_2 (20 cm^3) and pouring into saturated aq. $NaHCO_2$–NaCl (1:1; 50 cm^3). The aqueous layer was adjusted to pH 7–8 by addition of solid $NaHCO_3$, the organic layer was separated, and the water layer was re-extracted with CH_2Cl_2 (3 × 50 cm^3). The combined organic phases were dried ($MgSO_4$), and evaporated under reduced pressure, and the residue (containing solid PhHgCl, sparingly soluble in ethyl acetate) was purified twice by flash chromatography (70% ethyl acetate–light petroleum) to obtain the *diol* **28** (118 mg, 85%) as a foam; ν_{max}(film)/cm^{-1} 3446br s, 3058w, 2966s, 2904m, 2875m, 1723s, 1698s, 1588w, 1479m, 1434m, 1283m, 1198m, 1157s, 1080m, 1064m, 974m, 908m, 850m and 735m; δ_H(500 MHz) 6.89 (1 H, d, *J* 10.1, 6-H), 6.06 (1 H, d, *J* 10.1, 7-H), 4.75 (1 H, d, *J* 14.3, 8a-H), 4.60 (1 H, br s, 3-H), 4.29 (1 H, br s, 5-H), 4.16 (1 H, d, *J* 8.4, 2-H), 4.16–4.09 (2 H, m, 2′-H), 4.05 (1 H, d, *J* 8.4, 2-H), 3.77 (3 H, s, CO_2Me), 3.35 (1 H, br s, OH), 3.14 (1 H, br s, OH), 3.08 (1 H, d, *J* 14.3, 8b-H), 2.31 (1 H, dt, *J* 15.9, 2.8, 4-H), 2.24 (1 H, dt, *J* 15.9, 2.9, 4-H), 1.90 (1 H, dt, *J* 14.4, 6.8, 1′-H), 1.63 (1 H, dt, *J* 14.3, 7.0, 1′-H) and 1.18 (9 H, s, Bu^t); δ_C(125.8 MHz) 196.7 (C-8), 178.2 (CO_2R), 174.2 (CO_2R'), 153.4 (C-6), 130.4 (C-7), 76.5, 73.2, 71.3, 66.9, 60.5, 52.7, 52.2, 45.8, 44.2, 38.6 and 33.4, 29.6 and 27.1 [3 C, CMe_3]; *m*/*z* (EI) 396 (M^+, 0.3%), 378 (M^+ − H_2O, 0.1), 360 (M^+ − $2H_2O$, 0.1), 294 (M^+ − Bu$^t CO_2H$, 1.3), 276 (M^+ − Bu$^t CO_2H$ − H_2O, 1.5), 266 (0.9), 258 (M^+ − Bu$^t CO_2H$ − $2H_2O$, 0.8), 249 (2.3), 136 (100) and 57 (Bu^{t+}, 80) (Found: M^+, 396.1784. $C_{20}H_{28}O_8$ requires M, 396.1784).

(2aR*,3S*,5R*,5aS*,8aS*,8bS*)-*Methyl* 3,5-[(S*)-*Benzylidenedioxy*]-8-*oxo*-5a-(2′-*pivaloyloxyethyl*)-4,5,5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **29**.—A mixture of the diol **28** (777 mg, 1.96 mmol), freshly distilled benzaldehyde (1.5 cm^3, 14.8 mmol) and PPTS (80 mg, 0.32 mmol) in anhydrous benzene (40 cm^3) was heated to reflux with azeotropic removal of water (Dean–Stark). After 7.5 h, further PPTS (10 mg, 0.04 mmol) was added and the mixture was heated for a further 17 h. After cooling, the mixture was poured into saturated aq. $NaHCO_3$ (40 cm^3) and extracted with CH_2Cl_2 (4 × 60 cm^3). The combined extracts were dried ($MgSO_4$), and evaporated under reduced pressure, and the residue was purified by flash chromatography (70% diethyl ether–light petroleum; then gradient elution with 65–100% ethyl acetate–light petroleum) to obtain, in order of elution, the *benzylidene acetal* **29** (784 mg, 83%) as a foam; ν_{max}(film)/cm^{-1} 2969m, 1727s, 1698s, 1481m, 1457m, 1285m, 1157s, 1098s, 981m, 731m and 700m; δ_H(500 MHz) 7.39–7.27 (5 H, m, Ph), 6.99 (1 H, d, *J* 10.1, 6-H), 6.18 [1 H, s, $PhCH(OR)_2$], 6.10 (1 H, d, *J* 10.1, 7-H), 4.93 (1 H, br d, *J* 4.5, 3-H), 4.79 (1 H, d, *J* 14.8, 8a-H), 4.67 (1 H, br d, *J* 4.5, 5-H), 4.23–4.09 (2 H, m, 2′-H_2), 4.05 (1 H, d, *J* 8.5, 2-H), 4.01 (1 H, d, *J* 8.4, 2-H), 3.81 (3 H, s, CO_2Me), 3.64 (1 H, d, *J* 14.7, 8b-H), 2.95 (1 H, dt, *J* 16.1, 4.8, 4-H_{eq}), 2.10 (1 H, br d, *J* 16.2, 4-H_{ax}), 2.01 (1 H, dt, *J* 14.7, 6.5, 1′-H), 1.83 (1 H, dt, *J* 14.7, 7.1, 1′-H) and 1.19 (9 H, s, Bu^t); *m*/*z* (EI) 484 (M^+, 0.4%), 483 (M^+ − H, 0.4), 425 (M^+ − OMe − CO, 0.1), 382 (M^+ − Bu$^t CO_2H$, 0.9), 378 (M^+ − PhCHO, 0.8), 369 (1.4), 349 (0.6), 276 (M^+ − Bu$^t CO_2H$ − PhCHO, 11), 249 (M^+ − PhCHO − C_2H_4 − Bu$^t CO_2$, 12), 105 ($PhCO^+$, 24), 77 (Ph^+, 17) and 57 (Bu^{t+}, 100) (Found: M^+, 484.2095; C, 66.7; H, 6.7%. $C_{27}H_{32}O_8$ requires M, 484.2097; C, 66.9; H, 6.7%); and the starting diol **28** (95 mg, 12% recovery).

(1R*,4aR*,6S*,8aS*)-6-tert-*Butyldimethylsiloxy*-8a-(*prop*-2′-*enyl*)-1-(1,3,6-*trioxaheptyl*)-1,2,3,4,4a,5,6,8a-*octahydronaphthalene* **31**.—Sodium borohydride (0.2 g, 5.29 mmol) was added portionwise to a stirred solution of the enone **30**[27] (1.03 g, 3.48 mmol) and cerium(III) chloride heptahydrate (1.49 g, 4 mmol) in methanol (20 cm^3) at 0 °C. The mixture was stirred for 30 min, then saturated aq. NH_4Cl (40 cm^3) was added slowly and the mixture was stirred until effervescence had ceased. Extraction of the mixture with CH_2Cl_2 (4 × 50 cm^3), drying of the combined organic layers ($MgSO_4$), and evaporation under reduced pressure gave an oil. Purification by flash chromatography (65% diethyl ether–light petroleum) afforded (2R*,4aR*,5S*,8aS*)-4a-(*prop*-2′-*enyl*)-5-(1,3,6-*trioxaheptyl*)-1,2,4a,5,6,7,8,8a-*octahydro*-2-*naphthol* (850 mg, 82%) as an oil; ν_{max}(film)/cm^{-1} 3414m, 3069w, 3020w, 2933s, 2869s, 1632m, 1451m, 1129s, 1108s, 1091s, 1040s, 906m, 847m, and 766m; δ_H(500 MHz) 5.94 (1 H, dddd, *J* 5.4, 9.4, 9.9, 17.1, 2′-H), 5.90 (1 H, dd, *J* 1.6, 10.3, 4-H), 5.67 (1 H, ddd, *J* 1.3, 2.3, 10.2, 3-H), 4.96 (1 H, m, includes d, *J* 17.1, 3′-H_{trans}), 4.92 (1 H, m, includes d, *J* 10.0, 3′-H_{cis}), 4.79 (1 H, d, *J* 7.0, OCH_2O), 4.68 (1 H, d, *J* 7.0, OCH_2O), 4.27 (1 H, ddt, *J* 7.2, 9.4, 2.1, 2-H), 3.76–3.66 (2 H, m, $MeOCH_2CH_2O$), 3.55 (2 H, t, *J* 4.7, $MeOCH_2CH_2O$), 3.39 (3 H, s, OMe), 3.26 (1 H, dd, *J* 4.6, 11.4, 5-H), 2.49 (1 H, ddt, *J* 5.4, 14.5, 1.9, 1′-H), 2.24 (1 H, br dd, *J* 9.3, 14.5, 1′-H), 1.94–1.87 (1 H, m, 6-H_{eq}), 1.80–1.72 (2 H, m, 7-H_{eq}, 1-H), 1.70–1.56 (2 H, m, 1-H, 6-H_{ax}), 1.45–1.30 (4 H, m, OH, 8a-H and 7- and 8-H_{ax}) and 1.26–1.21 (1 H, m, 8-H_{eq}); *m/z* (EI) 296 (M^+, 0.1%), 278 ($M^+ - H_2O$, 0.1), 237 ($M^+ - MeOC_2H_4$, 0.2), 220 ($M^+ - MeOC_2H_4OH$, 0.9), 207 ($M^+ - MeOC_2H_4OCH_2$, 1), 190 ($M^+ - MeOC_2H_4OCH_2OH$, 3.8), 172 ($M^+ - MeOC_2H_4OCH_2OH - H_2O$, 1.9), 149 ($M^+ - MeOC_2H_4OCH_2OH - C_3H_5$, 53), 131 ($M^+ - MeOC_2H_4OCH_2OH - C_3H_5 - H_2O$, 30), 89 ($MeOC_2H_4OCH_2^+$, 70) and 59 ($MeOC_2H_4^+$, 100) (Found: $M^+ - H_2O$, 278.1880. $C_{17}H_{26}O_3$ requires $M - H_2O$, 278.1882).

tert-Butyldimethylsilyl chloride (500 mg, 3.32 mmol) was added in one portion to a stirred solution of (2R*,4aR*,5S*,8aS*)-4a-(prop-2-enyl)-5-(1,3,6-trioxaheptyl)-1,2,4a,5,6,7,8,8a-octahydro-2-naphthol (850 mg, 2.87 mmol) and imidazole (250 mg, 3.67 mmol) in anhydrous DMF (5 cm^3). After 45 min, the solution was poured into saturated aq. NH_4Cl (70 cm^3) and the mixture was extracted with CH_2Cl_2 (3 × 50, 1 × 20 cm^3). The combined extracts were dried ($MgSO_4$) and the solvent was removed under reduced pressure. Purification of the residue by flash chromatography (10% diethyl ether–light petroleum) gave the *silyl ether* **31** (1.08 g, 91%) as an oil; ν_{max}(film)/cm^{-1} 3068w, 3020w, 2928s, 2855m, 1633w, 1459m, 1250m, 1090s, 1068s, 1042s, 872m, 835m and 775m; δ_H(500 MHz) 5.99 (1 H, dddd, *J* 5.6, 8.9, 10.0, 17.1, 2′-H), 5.81 (1 H, dd, *J* 1.9, 10.2, 8-H), 5.56 (1 H, ddd, *J* 1.4, 2.0, 10.3, 7-H), 4.96 (1 H, m, includes d, *J* 17.1, 3′-H_{trans}), 4.90 (1 H, m, includes d, *J* 10.0, 3′-H_{cis}), 4.78 (1 H, d, *J* 7.0, OCH_2O), 4.67 (1 H, d, *J* 7.0, OCH_2O), 4.28 (1 H, ddt, *J* 7.0, 9.3, 2.1, 6-H), 3.76–3.65 (2 H, m, $MeOCH_2CH_2O$), 3.55 (2 H, t, *J* 4.7, $MeOCH_2CH_2O$), 3.39 (3 H, s, OMe), 3.25 (1 H, dd, *J* 4.6, 11.5, 1-H), 2.48 (1 H, ddt, *J* 5.6, 14.5, 1.8, 1′-H), 2.23 (1 H, br dd, *J* 8.9, 14.5, 1′-H), 1.92–1.86 (1 H, m, 2-H_{eq}), 1.80–1.73 (1 H, m, 3-H_{eq}), 1.75–1.66 (1 H, m, 5-H), 1.66–1.58 (1 H, m, 2-H_{ax}), 1.56 (1 H, br dd, *J* 7.0, 12.5, 5-H), 1.44–1.30 (3 H, m, 3-and 4-H_{ax}, 4a-H), 1.22–1.16 (1 H, m, 4-H_{eq}), 0.89 (9 H, s, Bu^t), 0.06 (3 H, s, Me) and 0.05 (3 H, s, Me); *m/z* (EI, 9 eV) 410 (M^+, 1.8%), 369 ($M^+ - C_3H_5$, 0.5), 353 ($M^+ -$ Bu^t, 4.8), 321 ($M^+ - MeOC_2H_4OCH_2$, 3.6), 304 ($M^+ - MeOC_2H_4OCH_2OH$, 1.2), 279 ($M^+ -$ Bu^{t}Me$_2$SiO, 6.4), 263 ($M^+ - MeOC_2H_4OCH_2OH - C_3H_5$, 15), 247 (20), 173 ($M^+ -$ Bu^{t}Me$_2$SiO $- MeOC_2H_4OCH_2OH$, 18) and 89 ($MeOC_2H_4OCH_2^+$, 100) Found; $M^+ -$ Bu^t, 353.2142. $C_{19}H_{33}O_4Si$ requires *m/z*, 353.2148).

[(2R*,4aR*,5S*,8aS*)-2-tert-*Butyldimethylsiloxy*-5-(1,3,6-*trioxaheptyl*)-1,2,5,6,7,8,8a-*octahydro*-4a-*naphthyl*]*acetaldehyde* **32**.—Osmium tetraoxide (4 crystals) was added to a stirred solution of the alkene **31** (1.05 g, 2.57 mmol) and *N*-methylmorpholine *N*-oxide (0.33 g of a 97% pure material, 2.69 mmol) in *tert*-butyl alcohol–THF–water (10:3:1; 18 cm^3). After 2 h, a slurry of saturated aq. Na_2SO_4 and talc (2.5 cm^3) was added. The mixture was stirred for a further 30 min and was then filtered, and the filter was washed thoroughly with CH_2Cl_2. The solvent was evaporated off under reduced pressure and the resultant orange oil was dissolved in methanol–water (4:1; 30 cm^3). Sodium periodate (1.46 g, 6.78 mmol) was added in one portion to the vigorously stirred solution. After 5 min, saturated aq. Na_2SO_3 (7 cm^3) was added, and the mixture was diluted with water (30 cm^3) and extracted with CH_2Cl_2 (3 × 80 cm^3). The combined organic extracts were dried ($MgSO_4$) and the solvent was removed under reduced pressure. Purification of the residue by flash chromatography (35% diethyl ether–light petroleum) gave the *aldehyde* **32** (832 mg, 79% overall) as an oil; ν_{max}(film)/cm^{-1} 3025w, 2933s, 2855s, 2743w, 1713s, 1460m, 1251m, 1102s, 1071s, 1040s, 871s, 837s and 777s; δ_H(500 MHz) 9.78 (1 H, br d, *J* 4.9, CHO), 6.20 (1 H, br d, *J* 10.2, 4-H), 5.66 (1 H, dd, *J* 1.0, 9.3, 3-H), 4.79 (1 H, d, *J* 7.1, OCH_2O), 4.66 (1 H, d, *J* 7.1, OCH_2O), 4.38–4.32 (1 H, m, 2-H), 3.70–3.60 (2 H, m, $MeOCH_2CH_2O$), 3.53 (2 H, t, *J* 4.6, $MeOCH_2CH_2O$), 3.37 (3 H, s, OMe), 3.32 (1 H, dd, *J* 4.6, 11.4, 5-H), 2.72 (1 H, dd, *J* 5.0, 14.9, CH_2CHO), 2.34 (1 H, br d, *J* 14.9, CH_2CHO), 2.00–1.93 (1 H, m, 6-H_{eq}), 1.82–1.75 (1 H, m, 7-H_{eq}), 1.71 (1 H, br dd, *J* 6.9, 11.2, 1-H), 1.59–1.45 (3 H, m, 1-, 8a-H and 6-H_{ax}), 1.40–1.17 (3 H, m, 7-H_{ax}, and 8-H_2), 0.88 (9 H, s, Bu^t), 0.07 (3 H, s, Me) and 0.06 (3 H, s, Me); *m/z* (EI) 368 ($M^+ - C_2H_4O$, 0.6%), 355 ($M^+ -$ Bu^t, 0.1), 337 ($M^+ - MeOC_2H_4O$, 0.1), 323 ($M^+ - MeOC_2H_4OCH_2$, 0.9), 307 ($M^+ - MeOC_2H_4OCH_2O$, 2.9), 263 ($M^+ - MeOC_2H_4OCH_2OH - CH_2CHO$, 8.6), 249 ($M^+ -$ Bu^t $- MeOC_2H_4OCH_2OH$, 44), 223 (30), 131 (62), 89 ($MeOC_2H_4OCH_2^+$, 70), 75 (Me_2SiOH^+, 45) and 59 ($MeOC_2H_4^+$, 100) (Found: $M^+ -$ Bu^t, 355.1936. $C_{18}H_{31}O_5Si$ requires *m/z*, 355.1941).

[(2R*,4aR*,5S*,8aS*)-2-tert-*Butyldimethylsiloxy*-5-(1,3,6-*trioxaheptyl*)-1,2,4a,5,6,7,8,8a-*octahydro*-4a-*naphthyl*]*methanol* **33**.—Butyllithium (455 mm^3 of a 2.5 mol dm^{-3} solution in hexanes, 1.14 mmol) was added *via* syringe to a stirred solution of diisopropylamine (116 mm^3, 1.18 mmol) in THF (1.2 cm^3) at 0 °C under argon. After 30 min, the lithium diisopropylamine (LDA) solution was cooled to −78 °C and a solution of the aldehyde **32** (300 mg, 0.73 mmol) in THF (1.8 cm^3 + 2 × 0.3 cm^3 rinsings) was added *via* cannula. The solution was stirred for 30 min at −78 °C and then 1,3-dimethyl-3,4,5,6-tetrahydropyrimid-2(1*H*)-one (500 mm^3) was added *via* syringe, followed by *tert*-butyldimethylsilyl chloride (freshly distilled; 770 mm^3 of a 1.5 mol dm^{-3} solution in diethyl ether, 1.16 mmol). After warming to room temperature, the reaction mixture was stirred for a further 2 h and was then quenched by addition of water (20 cm^3). The mixture was extracted with diethyl (3 × 30 cm^3) and the combined organic layers were washed with brine (15 cm^3), dried (Na_2SO_4), and concentrated under reduced pressure. Filtration of the residue through a short column of silica (35% diethyl ether–light petroleum) afforded, in order of elution, the crude silyl enol ether intermediate (330 mg, contaminated with silanol) and the starting aldehyde **32** (74 mg, 25% recovery) as oils. The silyl enol ether was used directly without further purification.

A trace amount of Sudan Red 7B was added to a solution of the crude silyl enol ether in CH_2Cl_2 (30 cm^3) to give a pale pink solution. After the mixture had been cooled to −78 °C, a stream of ozone (flow rate 40 dm^3 h^{-1}; ionizing voltage, 80 V) was passed through the stirred solution and the reaction was

monitored by the colour change of the indicator dye. The solution decolourized after 6.5 h and a TLC test indicated complete consumption of starting material. The flask was purged with argon, and triphenylphosphine (125 mg, 0.48 mmol) was added. The solution was allowed to warm slowly to room temperature during 12 h after which time the solvent was evaporated off under reduced pressure. Triphenylphosphine oxide was removed by filtration of the residue through a pad of silica (30% diethyl ether–light petroleum) to obtain the crude aldehyde intermediate as a pale yellow oil.

Sodium borohydride (25 mg, 0.66 mmol) was added portionwise to a solution of the aldehyde in methanol (2 cm^3) and the mixture was stirred until hydrogen evolution ceased (20 min). Evaporation of the solvent and purification of the residue by flash chromatography (50% diethyl ether–light petroleum) gave the *alcohol* **33** (120 mg, 41% overall) as an oil; ν_{max}(film)/cm^{-1} 3532m, 3025w, 2929s, 2855m, 1459m, 1251m, 1101m, 1068s, 1040s, 872m, 835m and 776m; δ_H(500 MHz) 6.08 (1 H, dd, *J* 1.9, 10.3, 4-H), 5.70 (1 H, dd, *J* 2.2, 10.3, 3-H), 4.83 (1 H, d, *J* 7.1, OCH_2O), 4.70 (1 H, d, *J* 7.1, OCH_2O), 4.33 (1 H, tt, *J* 2.1, 8.1, 2-H), 4.21 (1 H, d, *J* 10.9, CH_2OH), 3.76–3.65 (3 H, m, 1 H of CH_2OH and $MeOCH_2CH_2O$), 3.55 (2 H, t, *J* 4.7, $MeOCH_2CH_2O$), 3.45 (1 H, dd, *J* 4.5, 11.3, 5-H), 3.39 (3 H, s, OMe), 2.79 (1 H, v br, s, OH), 2.05–1.98 (1 H, m, 6-H_{eq}), 1.84–1.77 (1 H, m, 7-H_{eq}), 1.73–1.62 (3 H, m, 6-H_{ax} and 1-H_2), 1.47–1.32 (2 H, m, 8a-H, 7-H_{ax}), 1.29 (1 H, dq, *J* 3.5, 12.4, 8-H_{ax}) 1.23–1.17 (1 H, m, 8-H_{eq}), 0.88 (9 H, s, Bu^t), 0.06 (3 H, s, Me) and 0.05 (3 H, s, Me); *m/z* (EI) 400 (M^+, <0.1%), 399 (M^+ − H, 0.1), 369 (M^+ − CH_2OH, 0.1), 343 (M^+ − Bu^t, 0.1), 324 (M^+ − $MeOC_2H_4OH$, 1.3), 311 (M^+ − $MeOC_2H_4OCH_2$, 4.3), 295 (M^+ − $MeOC_2H_4OCH_2O$, 8.4), 263 (M^+ − $MeOC_2H_4OCH_2OH$, 21), 237 (53), 145 (76), 133 (45), 89 ($MeOC_2H_4OCH_2^+$, 59), 75 (Me_2SiOH^+, 100) and 59 ($MeOC_2H_4^+$, 86) (Found: M^+ − $MeOC_2H_4OCH_2O$, 295.2091. $C_{17}H_{31}O_2Si$ requires *m/z*, 295.2093).

[(2R*,4aR*,5S*,8aS*)-2-tert-*Butyldimethylsiloxy*)-5-(1,3,6-*trioxaheptyl*)-1,2,4a,5,6,7,8,8a-*octahydro*-4a-*naphthyl*]*methyl Cyanoacetate* **34**.—A solution of toluene-*p*-sulfonyl chloride (240 mg, 1.26 mmol) in CH_2Cl_2 (1 + 2 × 0.2 cm^3 rinsing) was added dropwise *via* cannula to a stirred solution of the alcohol **33** (252 mg, 0.63 mmol), cyanoacetic acid (160 mg, 1.88 mmol) and pyridine (350 mm^3, 4.33 mmol) in CH_2Cl_2 (2.5 cm^3). After 20 min, the reaction mixture was poured into saturated aq. NH_4Cl (15 cm^3) and extracted with CH_2Cl_2 (3 × 20 cm^3). The combined organic layers were washed with saturated $NaHCO_3$ (20 cm^3), and were then dried ($MgSO_4$), and evaporated under reduced pressure. Purification of the residue by flash chromatography (45% diethyl ether–light petroleum) gave the *cyanoacetate* **34** (276 mg, 94%) as a pale yellow oil; ν_{max}(film)/cm^{-1} 3026w, 2929s, 2856s, 2258w, 1751s, 1468m, 1334m, 1252s, 1180s, 1040s, 870s, 836s and 779m; δ_H(500 MHz) 5.83 (1 H, dd, *J* 1.8, 10.2, 4-H), 5.64 [1 H, ddd, *J* 0.6 (long-range coupling to 1-H), 2.5, 10.1, 3-H], 4.92 (1 H, d, *J* 11.4, CH_2O_2CR), 4.81 (1 H, d, *J* 7.1, OCH_2O), 4.68 (1 H, d, *J* 7.1, OCH_2O), 4.32 (1 H, tt, *J* 2.2, 8.3, 2-H), 4.20 (1 H, d, *J* 11.4, CH_2O_2CR), 3.77–3.66 (2 H, m, $MeOCH_2CH_2O$), 3.55 (1 H, d, *J* 19.0, RO_2CCH_2CN), 3.55 (2 H, t, *J* 4.6, $MeOCH_2CH_2O$), 3.46 (1 H, d, *J* 19.0, RO_2CCH_2CN), 3.39 (3 H, s, OMe), 3.31 (1 H, dd, *J* 4.7, 11.3, 5-H), 1.98–1.91 (1 H, m, 6-H_{eq}), 1.85–1.79 (1 H, m, 7-H_{eq}), 1.79–1.69 (2 H, m, 1-H_2), 1.51–1.31 (4 H, m, 6- and 7-H_{ax}, 8-H_2 and 8a-H), 0.89 (9 H, s, Bu^t), 0.072 (3 H, s, Me) and 0.066 (3 H, s, Me); *m/z* (EI) 467 (M^+, <0.1%), 466 (M^+ − H, 0.1), 452 (M^+ − Me, 0.1), 436 (M^+ − MeO, 0.1), 410 (M^+ − Bu^t, 15), 362 (M^+ − $MeOC_2H_4OCH_2O$, 5.4), 334 (M^+ − Bu^t − $MeOC_2H_4OH$, 3.5), 304 (M^+ − Bu^t − $MeOC_2H_4OCH_2OH$, 7.8), 263 (M^+ − $MeOC_2H_4OCH_2OH$ − $CH_2O_2CCH_2CN$, 5.1), 237 (7.1), 145 (44), 89 ($MeOC_2H_4OCH_2^+$, 100), 75 (Me_2SiOH^+, 33), 59 ($MeOC_2H_4^+$, 86) (Found: M^+ − Bu^t, 410.1994. $C_{20}H_{32}NO_6Si$ requires *m/z*, 410.1999).

[(2R*,4aR*,5S*,8aS*)-2-*Hydroxy*-5-(1,3,6-*trixaheptyl*)-1,2,4a,-5,6,7,8,8a-*octahydro*-4a-*naphthyl*]*methyl Cyanoacetate* **35**.—Pyridine (270 mm^3, 3.34 mmol) was added to a solution of the silyl ether **34** (276 mg, 0.59 mmol) in acetonitrile (2.4 cm^3) in a plastic flask, followed by HF (0.13 cm^3 of a 40% aq. solution, 3.0 mmol). The mixture was stirred at 27 °C for 26 h, then was poured into saturated aq. $NaHCO_3$ (15 cm^3) and extracted with CH_2Cl_2 (3 × 25 cm^3). The combined extracts were dried ($MgSO_4$), and evaporated under reduced pressure, and the residue was purified by flash chromatography (Et_2O) to obtain the *alcohol* **35** (205 mg, 98%) as an oil; ν_{max}(film)/cm^{-1} 3445m, 3016w, 2929m, 2870m, 2255w, 1745s, 1451m, 1333m, 1253m, 1183m, 1096m and 1034s; δ_H(500 MHz) 5.86 (1 H, br d, *J* 11.0, 4-H), 5.84 (1 H, br d, *J* 11.0, 3-H), 4.81 (1 H, d, *J* 7.1, OCH_2O), 4.70 (1 H, d, *J* 11.6, CH_2O_2CR), 4.69 (1 H, d, *J* 7.1, OCH_2O), 4.33 (1 H, d, *J* 11.6, CH_2O_2CR), 4.29 (1 H, br dd, *J* 7.2, 9.5, 2-H), 3.76–3.67 (2 H, m, $MeOCH_2CH_2O$), 3.54 (2 H, t, *J* 4.7, $MeOCH_2CH_2O$), 3.51 (1 H, d, *J* 19.3, RO_2CCH_2CN), 3.46 (1 H, d, *J* 19.3, RO_2CCH_2CN), 3.38 (3 H, s, OMe), 3.34 (1 H, m, includes d, *J* 11.3, 5-H), 2.1 (1 H, v br s, OH), 1.99–1.92 (1 H, m, 6-H_{eq}), 1.89 [1 H, ddd, *J* 2.4 (long-range coupling to 3-H), 7.1, 12.5, 1-H], 1.84–1.79 (1 H, m, 7-H_{eq}), 1.74 (1 H, dt, *J* 9.6, 12.8, 1-H) and 1.53–1.36 (5 H, m, 6- and 7-H_{ax}, 8-H_2 and 8a-H); *m/z* (EI) 277 (M^+ − $MeOC_2H_4OH$, 0.5%), 264 (M^+ − $MeOC_2H_4OCH_2$, 0.6), 259 (M^+ − $MeOC_2H_4OH$ − H_2O, 0.2), 248 (M^+ − $MeOC_2H_4OCH_2O$, 1.2), 230 (M^+ − $MeOC_2H_4OCH_2O$ − H_2O, 0.5), 179 (3.9), 89 ($MeOC_2H_4OCH_2^+$, 87) and 59 ($MeOC_2H_4^+$, 100) (Found: M^+ − $MeOC_2H_4OCH_2$, 264.1239. $C_{14}H_{18}NO_4$ requires *m/z*, 264.1236) (Found: C, 61.05; H, 7.8; N, 3.9. $C_{18}H_{27}NO_6$ requires C, 61.2; H, 7.7; N, 4.0%).

(4RS,4aR*,7aR*,11R*,11aS*)-3,6-*Dioxo*-11-(1,3,6-*trioxaheptyl*)*perhydronaphtho*[8a,1-c]*pyran*-4-*carbonitrile* **37**.—PDC (70 mg, 0.19 mmol) was added to a stirred slurry of the allylic alcohol **35** (55 mg, 0.16 mmol) and powdered activated 4 Å molecular sieves (20 mg) in CH_2Cl_2 (1 cm^3). After 2 h, the mixture was diluted with ethyl acetate (1 cm^3) and filtered through a plug of Florisil, which was then washed thoroughly with ethyl acetate. The filtrate was evaporated under reduced pressure to give the crude enone **36** as an oil.

The crude enone **36** was dissolved in CH_2Cl_2 (1 cm^3) and DBU (~1 mm^3) was added to the stirred solution. After 1 h, further DBU (~1 mm^3) was added and again after 2 h. After a further 1 h, the solvent was evaporated off under reduced pressure and the resulting orange residue was purified by flash chromatography (80% ethyl acetate–light petroleum) to obtain the *lactone* **37** (50 mg, 91%, inseparable 6.7:1 mixture at C-4) as an oil; ν_{max}(film)/cm^{-1} 2922m, 2258w, 1761s, 1714s, 1450m, 1278m, 1196m, 1116m, 1019s and 731m; δ_H(500 MHz) 4.92 (1 H, d, *J* 7.3, OCH_2O), 4.75 (1 H, d, *J* 7.3, OCH_2O), 4.58 (1 H, br d, *J* 4.6, 4-H), 4.55 (1 H, d, *J* 12.8, 1-H), 4.43 [1 H, dd, *J* 1.0 (long-range coupling to 7a-H), 12.8, 1-H], 3.79 (1 H, ddd, *J* 2.9, 6.5, 10.8, $MeOCH_2CH_2O$), 3.72 (1 H, dd, *J* 4.4, 12.7, 11-H), 3.71 (1 H, ddd, *J* 2.6, 5.8, 10.8, $MeOCH_2CH_2O$), 3.65–3.53 (2 H, m, $MeOCH_2CH_2O$), 3.40 (3 H, s, OMe), 3.23 (1 H, ddd, *J* 1.5, 4.6, 10.2, 4a-H), 2.90 (1 H, dd, *J* 10.2, 16.5, 5-H), 2.55 (1 H, br d, *J* 16.5, 5-H), 2.39 (1 H, dd, *J* 5.3, 19.0, 7-H), 2.28 (1 H, dd, *J* 13.4, 19.0, 7-H), 2.18–2.06 (1 H, m, 7a-H), 1.99 (1 H, br ddt, *J* 3.5, 13.6, 3.2, 10-H_{eq}), 1.88–1.82 (1 H, m, 9-H_{eq}), 1.72–1.66 (1 H, m, 8-H_{eq}), 1.46–1.29 (2 H, m, 9- and 10-H_{ax}) and 1.10 (1 H, dq, *J* 4.0, 13.1, 8-H_{ax}); *m/z* (EI) 351 (M^+, 0.1%), 320 (M^+ − OMe, 0.1), 319 (M^+ − MeOH, 0.1), 306 (M^+ − $MeOCH_2$, 0.1), 292 (M^+ − $MeOC_2H_4$, 0.7), 276 (M^+ − $MeOC_2H_4O$, 2), 262 (M^+ − $MeOC_2H_4OCH_2$, 1.1), 246 (M^+ − $MeOC_2H_4OCH_2O$, 5.3), 89 ($MeOC_2H_4OCH_2^+$, 98) and 59 ($MeOC_2H_4^+$, 100) (Found: M^+, 351.1685. $C_{18}H_{25}NO_6$ requires M, 351.1682).

(3R*,3aR*,6aS*,10S*,10aR*)-*Methyl* 3-*Hydroxy*-5-*oxo*-10-(1,3,6-*trioxaheptyl*)*perhydronaphtho*[1,8a-c]*furan*-3-*carboxylate* **38**.—The cyano ester **37** (23.5 mg, 66.9 μmol) was dissolved in CH_2Cl_2 (2 cm^3) and pH 8 buffer [Aldrich, Hydrion; the contents of 1 sachet were dissolved in distilled water (250 cm^3) (1 cm^3)] was added. After the mixture had been cooled to 0 °C, MCPBA (29 mg of ~50% pure material, 84 μmol) was added portionwise to the vigorously stirred mixture. After 1.5 h, further MCPBA (46 mg, ~0.133 mmol) and pH 8 buffer (0.5 cm^3) were added, followed by $NaHCO_3$ (11 mg, 0.13 mmol). The mixture was stirred for a further 1 h and then further MCPBA (23 mg, 66.6 μmol) and $NaHCO_3$ (6 mg, 71 μmol) were added. After 5 min, excess of oxidant was reduced by addition of saturated aq. Na_2SO_3 (0.5 cm^3) at 0 °C and the mixture was stirred for a further 5 min. The aqueous layer was extracted with CH_2Cl_2 (13 × 4 cm^3) and the combined extracts were dried (Na_2SO_4) and evaporated. The residue was dried in a desiccator over phosphorus pentaoxide *in vacuo* for 1.25 h and was then dissolved in anhydrous methanol (2.5 cm^3). After addition of triethylamine (40 mm^3, 0.287 mmol) the solution was stirred at room temperature for 4.5 h whereupon the volatiles were evaporated off under reduced pressure. Residual triethylamine was removed under vacuum (0.1 mmHg) for 10 min. The residue was then dissolved in CH_2Cl_2 (5 cm^3) and a stream of CH_2N_2/argon (generated†[41] from 400 mg of Diazald®) was passed through the solution. When all the CH_2N_2 had been dissipated the solution was evaporated and the residue was purified by flash chromatography (90% ethyl acetate–light petroleum) to obtain the *perhydronaphthofuran* **38** (14.8 mg, 59%, inseparable 8:1 mixture at C-3) as an oil; ν_{max}(film)/cm^{-1} 3381m, 2933s, 2883s, 1743s, 1711s, 1448m, 1283m, 1210m, 1090s, 1038s and 846m; δ_H(500 MHz; major isomer only) 4.91 (1 H, d, *J* 7.4, OCH_2O), 4.77 (1 H, d, *J* 7.4, OCH_2O), 4.30 (1 H, d, *J* 9.4, 1-H), 3.96 (1 H, br d, *J* 9.4, 1-H), 3.88 (1 H, ddd, *J* 3.2, 6.3, 10.9, $MeOCH_2CH_2O$), 3.81 (3 H, s, CO_2Me), 3.74 (1 H, ddd, *J* 3.1, 5.8, 10.5, $MeOCH_2CH_2O$), 3.75 (1 H, br s, OH), 3.62–3.51 (3 H, m, $MeOCH_2CH_2O$, 10-H), 3.38 (3 H, s, OMe), 3.28 (1 H, br d, *J* 5.4, 3a-H), 2.60 (1 H, dd, *J* 14.7, 18.2, 6-H), 2.36 (1 H, dd, *J* 6.1, 17.3, 4-H), 2.31 (1 H, dd, *J* 2.4, 17.3, 4-H), 2.25–2.18 (1 H, m, 9-H_{eq}), 2.14 (1 H, dd, *J* 3.1, 18.2, 6-H), 1.82–1.74 (1 H, m, 8-H_{eq}), 1.67 (1 H, ddt, *J* 12.4, 14.7, 2.8, 6a-H), 1.51–1.35 (3 H, m, 7-H_{eq}, and 8- and 9-H_{ax}) and 0.98 (1 H, dq, *J* 3.72, 12.60, 7-H_{ax}); δ_C(125.8 MHz; major isomer only) 210.8 (1 C, s, C-5), 169.8 (1 C, s, CO_2Me), 103.6 (1 C, s, C-3), 94.0 (1 C, t, OCH_2O), 80.3 (1 C, d, C-10), 71.8 (1 C, t, $MeOCH_2CH_2O$), 68.3 (1 C, t, C-1), 67.3 (1 C, t, $MeOCH_2CH_2O$), 59.1 (1 C, q, $MeOCH_2CH_2O$), 53.3 (1 C, q, CO_2Me), 49.3 (1 C, s, C-10a), 45.3 (1 C, d, C-3a), 40.8 (1 C, t, C-6), 38.2 (1 C, d, C-6a), 36.5 (1 C, t, C-4), 29.3 (1 C, t, C-9), 28.0 (1 C, t, C-7) and 23.9 (1 C, t-C-8); *m/z* (EI) 313 (M^+ − OMe − CO, 0.8%), 296 (M^+ − $MeOC_2H_4OH$, 0.3), 283 (M^+ − $MeOC_2H_4OCH_2$, 0.3), 267 (M^+ − $MeOC_2H_4OCH_2O$, 1.4), 237 (1.6), 207 (11.4), 177 (1.5), 149 (4), 89 ($MeOC_2H_4OCH_2^+$, 79) and 59 ($MeOC_2H_4^+$, 100) (Found: M^+ − OMe − CO, 313.1651. $C_{16}H_{25}O_6$ requires *m/z*, 313.1651).

(3R*,3aR*,6aS*,10S*,10aR*)-*Methyl* 3-*Benzyloxy*-5-*oxo*-10-(1,3,6-*trioxaheptyl*)*perhydronaphtho*[1,8a-c]*furan*-3-*carboxylate* **39**.—Benzyl bromide (10 mm^3, 84 μmol) was added to a vigorously stirred slurry of the hemiketal **38** (5.6 mg, 15 μmol) and freshly prepared silver(I) oxide (10 mg, 43 μmol) in DMF (0.2 cm^3). After 6 h, the mixture was poured into saturated aq. NH_4Cl (7 cm^3) and extracted with CH_2Cl_2 (3 × 15 cm^3). The combined organic layers were dried ($MgSO_4$), and evaporated under reduced pressure. Purification of the residue by flash chromatography (80% ethyl acetate–light petroleum) gave the *benzyl ether* **39** (5 mg, 72%) as an oil; ν_{max}(film)/cm^{-1} 3060w, 3022w, 2933m, 2878m, 1744s, 1710s, 1450m, 1286m, 1209m, 1096s and 1037s; δ_H(500 MHz) 7.35–7.28 (2 H, m, Ph), 7.27–7.21 (3 H, m, Ph), 4.83 (1 H, d, *J* 7.4, OCH_2O), 4.70 (1 H, d, *J* 7.4, OCH_2O), 4.56 (1 H, d, *J* 11.9, OCH_2Ph), 4.43 (1 H, d, *J* 11.9, OCH_2Ph), 4.28 (1 H, d, *J* 9.5, 1-H_α), 3.74 (1 H, ddd, *J* 3.0, 6.9, 10.9, $MeOCH_2CH_2O$), 3.69 (3 H, s, CO_2Me), 3.67–3.61 (1 H, m, $MeOCH_2CH_2O$), 3.64 (1 H, d, *J* 9.5, 1-H), 3.56–3.44 (3 H, m, $MeOCH_2CH_2O$, 10-H), 3.36 (3 H, s, OMe), 2.95 (1 H, dd, *J* 1.4, 7.2, 3a-H), 2.72 (1 H, dd, *J* 1.4, 17.2, 4-H_β), 2.35 (1 H, dd, *J* 7.2, 17.2, 4-H_α), 2.28 (1 H, dd, *J* 14.6, 18.2, 6-H_β), 2.19–2.12 (1 H, m, 9-H_{eq}), 2.01 (1 H, dd, *J* 3.2, 18.2, 6-H_α), 1.78–1.70 (1 H, m, 8-H_{eq}), 1.63 (1 H, ddt, *J* 12.6, 14.6, 3.0, 6a-H), 1.49–1.27 (3 H, m, 8- and 9-H_{ax} and 7-H_{eq}) and 0.86 (1 H, dq, *J* 3.7, 12.7, 7-H_{ax}); *m/z* (EI) 403 (M^+ − OMe − CO, 4%), 356 (M^+ − $MeOC_2H_4OCH_2OH$, 1.3), 327 (M^+ − OMe − CO − $MeOC_2H_4OH$, 0.1), 297 (M^+ − OMe − CO − $MeOC_2H_4OCH_2OH$, 0.4), 280 (1.9), 267 (2.5), 207 (9.1), 91 ($C_7H_7^+$, 100), 89 ($MeOC_2H_4OCH_2^+$, 14) and 59 ($MeOC_2H_4^+$, 20) (Found: M^+ − OMe − CO, 403.2131. $C_{23}H_{31}O_6$ requires *m/z*, 403.2121).

(2aR*,3S*,5R*,5aS*,8R*,8aS*,8bS*)-*Methyl* 3,5[(S*)-*Benzylidenedioxy*]-8-*hydroxy*-5a-(2′-*pivaloyloxyethyl*)-4,5,5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **40** *and its* C(8) *Epimer* **41**.—Sodium borohydride (10 mg, 0.264 mmol) was added to a stirred solution of the enone **29** (88 mg, 0.182 mmol) and cerium(III) chloride heptahydrate (85 mg, 0.228 mmol) in methanol (10 cm^3) at 0 °C. After 10 min, the solvent was evaporated off under reduced pressure. CH_2Cl_2 was added to the residue and the resulting suspension was filtered, and the filter was washed thoroughly with CH_2Cl_2. Evaporation of the filtrate under reduced pressure and purification of the residue by flash chromatography (45% ethyl acetate–light petroleum) gave, in order of elution, the *allylic alcohol* **40** (39 mg, 44%) as a foam; ν_{max}(film)/cm^{-1} 3498m, 3060w, 3019w, 2958m, 1722s, 1623w, 1478m, 1396m, 1284m, 1200m, 1152s, 1101s, 979m, 762m and 701m; δ_H(500 MHz) 7.63–7.54 (2 H, m, Ph), 7.40–7.31 (3 H, m, Ph), 6.16 [1 H, s, $PhCH(OR)_2$], 6.04 (1 H, dd, *J* 4.3, 9.9, 7-H), 6.00 (1 H, d, *J* 9.9, 6-H), 4.91 (1 H, br d, *J* 4.6, 3-H), 4.51 (1 H, br d, *J* 4.6, 5-H), 4.48 (1 H, t, *J* 4.5, 8-H), 4.42 (1 H, dd, *J* 4.7, 12.6, 8a-H), 4.17–4.04 (2 H, m, 2′-H_2), 4.01 (1 H, d, *J* 8.3, 2-H), 3.98 (1 H, d, *J* 8.3, 2-H), 3.78 (3 H, s, CO_2Me), 3.67 (1 H, d, *J* 12.6, 8b-H), 2.89 (1 H, dt, *J* 16.0, 4.7, 4-H_{eq}), 2.65 (1 H, br s, OH), 2.09 (1 H, br d, *J* 16.0, 4-H_{ax}), 1.73 (1 H, ddd, *J* 5.8, 7.4, 14.3, 1′-H), 1.63 (1 H, dt, *J* 14.4, 7.5, 1′-H) and 1.18 (9 H, s, Bu^t); *m/z* (EI) 486 (M^+, 3.4%), 468 (M^+ − H_2O, 0.6), 384 (M^+ − Bu^tCO_2H, 0.3), 380 (M^+ − PhCHO, 3.8), 366 (M^+ − Bu^tCO_2H − H_2O, 0.2), 278 (M^+ − Bu^tCO_2H − PhCHO, 2.3), 105 ($PhCO^+$, 22), 77 (Ph^+, 19) and 57 (Bu^{t+}, 100) (Found: M^+, 486.2257; C, 66.7; H, 7.25. $C_{27}H_{34}O_8$ requires M, 486.2254; C, 66.65; H, 7.0%); and the *allylic alcohol* **41** (46.5 mg, 53%) as a foam; ν_{max}(film)/cm^{-1} 3428m, 2959m, 1720s, 1481m, 1457m, 1286m, 1156s, 1105s, 981m, 760m and 705m; δ_H(500 MHz) 7.41–7.32 (5 H, m, Ph), 6.18 [1 H, s, $PhCH(OR)_2$], 5.83 (1 H, dd, *J* 2.2, 10.0, 6- or 7-H), 5.73 (1 H, dd, *J* 2.2, 10.0, 7- or 6-H), 4.89 (1 H, br d, *J* 4.6, 3-H), 4.48 (1 H, br d, *J* 4.6, 5-H), 4.46 (1 H, br s, 8-H), 4.35 (1 H, dd, *J* 6.1, 12.9, 8a-H), 4.19–4.08 (2 H, m, 2′-H_2), 4.00 (1 H, d, *J* 8.3, 2-H), 3.91 (1 H, d, *J* 8.4, 2-H), 3.79 (3 H, s, CO_2Me), 3.28 (1 H, d, *J* 12.9, 8b-H), 2.87 (1 H, dt, *J* 16.1, 4.7, 4-H_{eq}), 2.38 (1 H, br s, OH), 2.12 (1 H, br d, *J* 16.0, 4-H_{ax}), 1.79 (1 H, ddd, *J* 5.8, 7.2, 14.3, 1′-H), 1.65 (1 H, dt, *J* 14.3, 7.6, 1′-H) and 1.18 (9 H, s, Bu^t); *m/z* (EI) 486 (M^+, 11%), 468 (M^+ − H_2O, 0.4), 384 (M^+ − Bu^tCO_2H, 0.5), 380 (M^+ − PhCHO, 2.8), 366 (M^+ − Bu^tCO_2H − H_2O, 0.2), 278 (M^+ − Bu^tCO_2H − PhCHO, 2.2), 105 ($PhCO^+$, 19) and 57 (Bu^{t+}, 100) (Found: M^+, 486.2257).

† Prepared according to ref. 41.

2aR*,3S*,5R*,5aS*,8R*,8aS*,8bS*)-*Methyl* 3,5-[(S*)-*Benzylidenedioxy*]-8-*hydroxy*-5a-(2′-*pivaloyloxyethyl*)-4,5,5a ,8,8a,-8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **40** *by Stereoselective Reduction of the Enone* **29**.—L-Selectride® (0.62 cm^3 of a 1 mol dm^{-3} solution in THF) was added dropwise *via* syringe to a vigorously stirred solution of the enone **29** (286 mg, 0.59 mmol) in THF (10 cm^3) under argon at −78 °C, and a yellow, fluorescent solution was formed. After 15 min, saturated aq. NH_4Cl (2.5 cm^3) was added and the mixture was allowed to warm to room temperature during 30 min. The now colourless solution was poured into saturated aq. NH_4Cl (40 cm^3) and extracted with CH_2Cl_2 (4 × 50 cm^3). The combined extracts were dried ($MgSO_4$), and evaporated under reduced pressure, and the residue was purified by flash chromatography (45% ethyl acetate–light petroleum) to obtain the allylic alcohol **40** (280 mg, 97%) as a foam, identical with the material prepared previously.

(2aR*,3S*,5R*,5aS*,8S*,8aS*,8bS*)-*Methyl* 3,5-[(S*)-*Benzylidenedioxy*]-*butyldimethylsiloxy*-5a-(2′-*pivaloyloxyethyl*)-4,5,-5a,8,8a, 8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **42**.—*tert*-Butyldimethylsilyl chloride (27 mg, 179 μmol) was added to a stirred solution of the alcohol **41** (35 mg, 72 μmol) and imidazole (20 mg, 294 μmol) in DMF (0.2 cm^3). The mixture was warmed to 35 °C for 2 h, then was allowed to cool and was poured into saturated aq. $NaHCO_3$ (10 cm^3). The aqueous layer was extracted with CH_2Cl_2 (3 × 15 cm^3), and the combined extracts were dried ($MgSO_4$), and evaporated under reduced pressure. Purification of the residue by flash chromatography (35% diethyl ether–light petroleum) gave the *silyl ether* **42** (42 mg, 97%) as an oil; ν_{max}(film)/cm^{-1} 2951m, 2930m, 2893m, 2852m, 1722s, 1470m, 1282m, 1252m, 1152m, 1104s, 1074m, 982m, 861m, 836m, 777m and 696m; δ_H(500 MHz) 7.43–7.33 (5 H, m, Ph), 6.18 [1 H, s, PhC*H*$(OR)_2$], 5.76 (1 H, dd, *J* 2.2, 10.0, 6- or 7-H), 5.63 (1 H, dd, *J* 2.2, 10.0, 7- or 6-H), 4.87 (1 H, br d, *J* 4.7, 3-H), 4.47 (1 H, br d, *J* 4.5, 5-H), 4.39 (1 H, dt, *J* 6.1, 2.2, 8-H), 4.27 (1 H, dd, *J* 6.1, 12.8, 8a-H), 4.12 (2 H, dd, *J* 6.8, 7.3, 2′-H_2), 3.95 (1 H, d, *J* 8.4, 2-H), 3.88 (1 H, d, *J* 8.4, 2-H), 3.77 (3 H, s, CO_2Me), 3.23 (1 H, d, *J* 12.8, 8b-H), 2.85 (1 H, dt, *J* 16.0, 4.7, 4-H_{eq}), 2.11 (1 H, br d, *J* 16.0, 4-H_{ax}), 1.81 (1 H, dt, *J* 14.3, 6.6, 1′-H), 1.63 (1 H, dt, *J* 14.3, 7.6, 1′-H), 1.18 (9 H, s, Bu^t), 0.95 (9 H, s, Bu^t), 0.18 (3 H, s, Me) and 0.17 (3 H, s, Me); *m/z* (EI) 600 (M^+, 11%), 585 (M^+ − Me, 0.2), 569 (M^+ − OMe, 0.1), 543 (M^+ − Bu^t, 22), 494 (M^+ − PhCHO, 1.6), 441 (M^+ − Bu$^t CO_2H$ − Bu^t, 0.9), 437 (M^+ − PhCHO − Bu^t, 2.4), 335 (M^+ − Bu$^t CO_2H$ − PhCHO − Bu^t), 19), 105 ($PhCO^+$, 21), 75 (Me_2SiOH^+, 80) and 57 (Bu^{t+}, 93) (Found: M^+, 600.3130. $C_{33}H_{48}O_8Si$ requires M, 600.3119).

(2aR*,3S*,5R*,5aS*,8S*,8aS*,8bS*)-*Methyl* 3,5-[(5*)-*Benzyl idenedioxy*]-8-tert-*butyldimethylsiloxy*-5a-(2′-*hydroxyethyl*)-4,5, 5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a- *carboxylate* **43**.—Water (0.30 cm^3) was added to a stirred solution of the pivalate **42** (37 mg, 61.6 μmol) in ethanol (96%; 3 cm^3), followed by lithium hydroxide monohydrate (18 mg, 429 μmol). The solution was heated to 60 °C for 5 h, then was cooled, and a stream of carbon dioxide was passed through the solution for 10 min. Phosphate buffer (0.6 cm^3; pH 5.5; prepared from saturated aq. Na_2HPO_4 and H_3PO_4) was added to the opaque solution and the mixture was extracted with CH_2Cl_2 (3 × 10 cm^3), followed by ethyl acetate (2 × 10 cm^3). The combined organic layers were dried ($MgSO_4$), and evaporated under reduced pressure. A stream of CH_2N_2/argon [generated[41] from Diazald® (200 mg)] was passed through a solution of the residue in CH_2Cl_2 (5 cm^3). When all the CH_2N_2 had been dissipated, the solution was evaporated and the residue was purified by flash chromatography (55% ethyl acetate–light petroleum) to obtain the *primary alcohol* **43** (21 mg, 66%) as an oil; ν_{max}(film)/cm^{-1} 3442m, 3018w, 2950s, 2926m, 2890m, 2854m, 1717s, 1470m, 1386m, 1252m, 1104s, 1073m, 981m, 860m, 836m, 778m and 697m; δ_H(500 MHz) 7.43–7.33 (5 H, m, Ph), 6.17 [1 H, s, PhC*H*$(OR)_2$], 5.78 (1 H, dd, *J* 2.2, 10.0, 6- or 7-H), 5.61 (1 H, dd, *J* 2.2, 9.9, 7- or 6-H), 4.87 (1 H, br d, *J* 4.7, 3-H), 4.49 (1 H, br d, *J* 4.6, 5-H), 4.38 (1 H, dt, *J* 6.0, 2.2, 8-H), 4.30 (1 H, dd, *J* 6.0, 12.8, 8a-H), 3.95 (1 H, d, 8.4, 2-H), 3.88 (1 H, d, *J* 8.4, 2-H), 3.78 (3 H, s, CO_2Me), 3.80–3.66 (2 H, m, 2′-H_2), 3.20 (1 H, d, *J* 12.8, 8b-H), 2.84 (1 H, dt, *J* 16.0, 4.7, 4-H_{eq}), 2.12 (1 H, br d, *J* 16.0, 4-H_{ax}), 1.75 (1 H, ddd, *J* 5.3, 7.5, 14.1, 1′-H), 1.58 (1 H, dt, *J* 14.1, 7.7, 1′-H), 1.35 (1 H, br, s, OH), 0.95 (9 H, s, Bu^t), 0.18 (3 H, s, Me) and 0.17 (3 H, s, Me); *m/z* (EI) 516 (M^+, 8%), 485 (M^+ − OMe, 0.2), 483 (M^+ − Me − H_2O, 0.2), 459 (M^+ − Bu^t, 1.7), 410 (M^+ − PhCHO, 0.9), 353 (M^+ − PhCHO − Bu^t, 3), 335 (M^+ − PhCHO − Bu^t − H_2O, 4), 105 ($PhCO^+$, 26), 75 (Me_2SiOH^+, 89) and 73 (100) (Found: M^+, 516.2536. $C_{28}H_{40}O_7Si$ requires M, 516.2543).

2aR*,3S*,5R*,5aS*,8S*,8aS*,8bS*)-*Methyl* 3,5-[(S*)-*Benzyl idenedioxy*]-8-tert-*butyldimethylsiloxy*-5a-*formylmethyl*-4,5,5a,-8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **44**.—Dess–Martin triacetoxyperiodinane reagent[35] (27 mg, 63.7 μmol) was added in one portion to a stirred solution of the alcohol **43** (20.5 mg, 39.7 μmol) and pyridine (27 mm^3, 330 μmol) in CH_2Cl_2 (1 cm^3). After 40 min, the mixture was poured into saturated aq. $NaHCO_3/Na_2S_2O_3$ (1:1; 10 cm^3) and extracted with CH_2Cl_2 (4 × 15 cm^3). The combined organic layers were dried ($MgSO_4$), and evaporated under reduced pressure. Purification of the residue by flash chromatography (60% diethyl ether–light petroleum) afforded the *aldehyde* **44** (18.5 mg, 91%) as a foam; ν_{max}(film)/cm^{-1} 3030w, 2950m, 2927m, 2894m, 2854m, 1719s, 1620w, 1468m, 1291m, 1254m, 1102s, 1074m, 982m, 861m, 837m, 778m and 697m; δ_H(500 MHz) 9.79 (1 H, t, *J* 2.2, CHO), 7.43–7.34 (5 H, m, Ph), 6.17 [1 H, s, PhC*H*$(OR)_2$], 5.93 (1 H, dd, *J* 2.2, 10.0, 6- or 7-H), 5.69 (1 H, dd, *J* 2.3, 9.9, 7- or 6-H), 4.88 (1 H, br d, *J* 4.7, 3-H), 4.54 (1 H, br d, *J* 4.6, 5-H), 4.39 (1 H, dt, *J* 6.1, 2.2, 8-H), 4.28 (1 H, dd, *J* 6.1, 12.8, 8a-H), 3.95 (1 H, d, *J* 8.5, 2-H), 3.90 (1 H, d, *J* 8.5, 2-H), 3.78 (3 H, s, CO_2Me), 3.24 (1 H, d, *J* 12.8, 8b-H), 2.87 (1 H, dt, *J* 16.1, 4.7, 4-H_{eq}), 2.68 (1 H, dd, *J* 2.1, 16.5, 1′-H), 2.29 (1 H, dd, *J* 2.3, 16.5, 1′-H), 1.94 (1 H, br d, *J* 16.1, 4-H_{ax}), 0.95 (9 H, s, Bu^t), 0.17 (3 H, s, Me) and 0.16 (3 H, s, Me); *m/z* (EI) 514 (M^+, 6.2%), 499 (M^+ − Me, 0.3), 471 (M^+ − C_2H_3O, 0.2), 457 (M^+ − Bu^t, 2.8), 439 (M^+ − Bu^t − H_2O, 1.3), 408 (M^+ − PhCHO, 3.7), 3.77 (M^+ − PhCHO − OMe, 1.2), 351 (M^+ − PhCHO − Bu^t, 28), 105 ($PhCO^+$, 26), 75 (Me_2SiOH^+, 85), 73 (100) and 57 (Bu^{t+}, 6.4) (Found: M^+, 514.2391. $C_{28}H_{38}O_7Si$ requires M, 514.2387).

2aR*,3S*,5R*,5aS*,8S*,8aS*,8bS*)-*Methyl* 3,5-[(S*)-*Benzyl-idenedioxy*]-8-tert-*butyldimethylsiloxy*-5a-[(E,Z)-2-tert-*butyl-dimethylsilyoxyvinyl*]-4,5,5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **45**.—*tert*-Butyldimethylsilyl triflate (20 mm^3, 103 μmol) was added dropwise *via* syringe to a stirred solution of the aldehyde **44** (18 mg, 35 μmol) and triethylamine (45 mm^3, 323 μmol) in CH_2Cl_2 under argon at −15 °C. After 45 min further triethylamine (20 mm^3, 143 μmol) and *tert*-butyldimethylsilyl triflate (10 mm^3, 51.7 μmol) were added, and again after 90 min [triethylamine (30 mm^3, 143 μmol) and *tert*-butyldimethylsilyl triflate (15 mm^3, 77.6 μmol)]. After a further 45 min, the reaction was quenched by addition of saturated aq. $NaHCO_3$ (0.8 cm^3) to the vigorously stirred mixture, which was then allowed to warm to room temperature. The mixture was poured into saturated aq. $NaHCO_3$ (5 cm^3) and extracted with CH_2Cl_2 (3 × 10 cm^3) and the combined organic layers were dried (Na_2SO_4), and evaporated under reduced pressure. Purification of the residue by flash chromatography (gradient elution, 20–80% diethyl ether–light petroleum) gave, in order of elution, the *silyl enol ether* **45** (16.5 mg, 75%,

inseparable 1:1.4 *E*:*Z* mixture) as an oil; ν_{max}(film)/cm^{-1} 3030w, 2951s, 2929s, 2888m, 2855m, 1721s, 1645m, 1468m, 1388m, 1253m, 1180m, 1122s, 1099s, 1073s, 1044m, 982m, 858m, 837s and 780m; δ_H(500 MHz) 7.45–7.34 (8.5 H, m, Ph_E, Ph_Z), 6.25 (0.7 H, d, *J* 12.0, 2′-H_E), 6.20 {0.7 H, s, [PhC*H*$(OR)_2$]$_E$}, 6.18 {1 H, s, [PhC*H*$(OR)_2$]$_Z$}, 6.08 (1 H, d, *J* 6.5, 2′-H_Z), 5.92 (1 H, dd, *J* 2.4, 9.8, 6- or 7-H_Z), 5.58 (0.7 H, dd, *J* 1.8, 9.7, 6- or 7-H_E), 5.54 (0.7 H, dd, *J* 1.8, 9.8, 7- or 6-H_E), 5.46 (1 H, dd, *J* 2.1, 9.8, 7- or 6-H), 5.11 (1 H, br d, *J* 4.9, 3-H_Z), 4.86 (0.7 H, d, *J* 12.1, 1′-H_E), 4.87–4.84 (1.7 H, m, 5-H_Z, 3-H_E), 4.43–4.37 (1.7 H, m, 8-$H_{E,Z}$), 4.32 (1 H, dd, *J* 6.2, 12.6, 8a-H_Z), 4.32–4.28 [0.7 H, m, (obscured by 1′-H_Z), 5-H_E], 4.30 (1 H, d, *J* 6.5, 1′-H_Z), 4.20 (0.7 H, dd, *J* 6.0, 12.6, 8a-H_E), 3.95 (1 H, d, *J* 8.3, 2-H_Z), 3.93 (0.7 H, d, *J* 8.3, 2-H_E), 3.87 (0.7 H, d, *J* 8.2, 2-H_E), 3.86 (1 H, d, *J* 8.3, 2-H_Z), 3.75 (3 H, s, CO_2Me_Z), 3.74 (2.1 H, s, CO_2Me_E), 3.21 (1 H, d, *J* 12.6, 8b-H_Z), 3.20 (0.7 H, d, *J* 12.6, 8b-H_E), 2.84 (0.7 H, dt, *J* 15.9, 4.7, 4-H_E), 2.77 (1 H, dt, *J* 15.7, 4.9, 4-H_Z), 2.30 (0.7 H, br d, *J* 15.9, 4-H_E), 2.13 (1 H, br d, *J* 15.7, 4-H_Z), 0.95 (9 H, s, Bu^t_Z], 0.94 (6.3 H, s, Bu^t_E), 0.91 (9 H, s, Bu^t_Z), 0.90 (6.3 H, s, Bu^t_E), 0.90 (6.3 H, s, Bu^t_E) and 0.18, 0.13, 0.12 and 0.02 (20.4 H, s, 4 × Me_Z, 4 × Me_E); *m*/*z* (EI) 628 (M^+, 10%), 571 (M^+ − Bu^t, 0.2), 522 (M^+ − PhCHO, 0.7), 465 (M^+ − PhCHO − Bu^t, 13.1), 433 (0.7), 405 (0.8), 105 ($PhCO^+$, 3.4), 75 (Me_2SiOH^+, 16) and 73 (100) (Found: M^+, 628.3242. $C_{34}H_{52}O_7Si_2$ requires M, 628.3252); and the starting material **44** (3.8 mg, 21% recovery).

(2a*R**,3*S**,5*R**,5a*R**,8*S**,8a*S**,8b*S**)-*Methyl* 3,5-[(*S**)-*Benzylidenedioxy*]-8-tert-*butyldimethylsiloxy*-5a-*formyl*-4,5,5a,8,8a,-8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **46**.—A trace amount of Sudan Red 7B was added to a solution of the silyl enol ether **45** (20 mg, 31.8 μmol) in CH_2Cl_2 (8 cm^3) to give a pale pink solution. After cooling of the mixture to −78 °C, a stream of ozone (flow rate dm^3 h^{-1}; ionizing voltage 75 V) was passed through the stirred solution and the reaction was monitored by colour change of the indicator dye and by TLC. After all the starting material had been consumed (~50 min), the flask was purged with argon and a solution of triphenylphosphine (12 mg, 45.8 μmol) in CH_2Cl_2 (1 cm^3) was added. The mixture was then allowed to warm slowly to room temperature during 12 h. Evaporation of the solvent under reduced pressure and purification of the residue by flash chromatography (30% diethyl ether–light petroleum) furnished the *aldehyde* **46** (13 mg, 82%) as an oil; ν_{max}(film)/cm^{-1} 3025w, 2951m, 2927m, 2894m, 2854m, 2737w, 1729s, 1708s, 1459m, 1388m, 1296m, 1254m, 1199m, 1139s, 1111s, 983m, 861m, 778m, 743m and 697m; δ_H(500 MHz) 9.62 (1 H, s, CHO), 7.42–7.35 (5 H, m, Ph), 6.17 [1 H, s, PhC*H*$(OR)_2$], 5.96 (1 H, dd, *J* 2.3, 9.7, 6- or 7-H), 5.47 (1 H, dd, *J* 2.3, 9.6, 7- or 6-H), 4.93 (1 H, br d, *J* 4.7, 3-H), 4.81 (1 H, br d, *J* 4.9, 5-H), 4.50 (1 H, dd, *J* 6.1, 13.1, 8a-H), 4.43 (1 H, dt, *J* 6.1, 2.3, 8-H), 4.08 (1 H, d, *J* 8.5, 2-H), 3.95 (1 H, d, *J* 8.5, 2-H), 3.72 (3 H, s, CO_2Me), 3.17 (1 H, d, *J* 13.1, 8b-H), 2.90 (1 H, dt, *J* 15.9, 4.9, 4-H_{eq}), 1.64 (1 H, br d, *J* 15.9, 4-H_{ax}), 0.95 (9 H, s, Bu^t), 0.18 (3 H, s, Me) and 0.17 (3 H, s, Me); *m*/*z* (EI) 500 (M^+, 0.3%), 499 (M^+ − H, 0.4), 485 (M^+ − Me, 0.2), 482 (M^+ − H_2O, 0.2), 469 (M^+ − OMe_2, 0.1), 443 (M^+ − Bu^t, 21), 394 (M^+ − PhCHO, 0.5), 379 (0.6), 337 (M^+ − PhCHO − Bu^t, 57), 319 (4.6), 305 (6.7), 105 ($PhCO^+$, 26), 75 (Me_2SiOH^+, 90) and 73 (100) (Found: M^+ − Bu^t, 443.1531. $C_{23}H_{27}O_7Si$ requires *m*/*z*, 443.1526).

(2a*R**,3*S**,5*R**,5a*S**,8*S**,8a*S**,8b*S**)-*Methyl* 3,5-[(*S**)-*Benzylidenedioxy*]-8-tert-*butyldimethylsiloxy*-5a-*cyanoacetoxymethyl*-4,5,5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **47**.—Zinc borohydride (130 mm^3 of a freshly prepared[42] 0.3 mol dm^{-3} solution in diethyl ether, 39 μmol) was added *via* syringe to a stirred solution of the aldehyde **46** (13 mg, 26 μmol) in THF (1 cm^3) at −10 °C under argon. After 25 min, further zinc borohydride (40 mm^3, 12 μmol) was added, and again after 1 h and 1.5 h. The solution was allowed to warm slowly to −5 °C during a further 75 min and then acetone (0.3 cm^3) was added. After warming, the mixture was poured into saturated aq. $NaHCO_3$ (7 cm^3) and extracted with CH_2Cl_2 (4 × 10 cm^3). The combined organic layers were dried (Na_2SO_4), and evaporated under reduced pressure. Remaining solvent was removed under high vacuum (0.02 mmHg) for 15 min before the residue was dissolved in anhydrous CH_2Cl_2 (0.4 cm^3). Pyridine (24 mm^3, 297 μmol) was added at 15 °C, followed by cyanoacetic acid (11 mg, 129 μmol) and toluene-*p*-sulfonyl chloride (15.5 mg, 81 μmol). After 15 min, the yellow solution was diluted with CH_2Cl_2 (15 cm^3) and poured into saturated aq. $NaHCO_3$ (7 cm^3), and the aqueous layer was re-extracted with CH_2Cl_2 (3 × 10 cm^3). The combined organic layers were dried ($MgSO_4$), and concentrated under reduced pressure. Purification of the residue by flash chromatography (70% diethyl ether–light petroleum) afforded the *cyanoacetate* **47** (13.7 mg, 93%) as a pale yellow oil; ν_{max}(film)/cm^{-1} 3030w, 2952s, 2928s, 2892m, 2854m, 2262w, 1751s, 1723s, 1624w, 1469m, 1388m, 1333m, 1253s, 1198m, 1110s, 1073m, 984m, 859m, 837m, 780m and 698m; δ_H(500 MHz) 7.42–7.35 (5 H, m, Ph), 6.17 [1 H, s, PhC*H*$(OR)_2$], 5.79 (1 H, dd, *J* 2.1, 10.0, 6- or 7-H), 5.68 (1 H, dd, *J* 2.2, 10.0, 7- or 6-H), 4.90 (1 H, br d, *J* 4.7, 3-H), 4.47 (1 H, br d, *J* 4.3, 5-H), 4.39 (1 H, d, *J* 11.3, CH_2O_2CR), 4.39 (1 H, dd, *J* 5.9, 12.7, 8a-H), 4.34 (1 H, dt, *J* 5.8, 2.2, 8-H), 4.13 (1 H, d, *J* 11.5, CH_2O_2CR), 3.95 (1 H, d, *J* 8.6, 2-H), 3.93 (1 H, d, *J* 8.5, 2-H), 3.80 (3 H, s, CO_2Me), 3.50 (2 H, s, RO_2CCH_2CN), 3.17 (1 H, d, *J* 12.7, 8b-H), 2.91 (1 H, dt, *J* 16.1, 4.7, 4-H_{eq}), 1.85 (1 H, br d, *J* 16.0, 4-H_{ax}), 0.94 (9 H, s, Bu^t), 0.17 (3 H, s, Me) and 0.16 (3 H, s, Me); *m*/*z* (EI) 569 (M^+, 0.9%), 554 (M^+ − Me, 0.8), 538 (M^+ − OMe, 0.1), 512 (M^+ − Bu^t, 36), 463 (M^+ − PhCHO, 0.6), 406 (M^+ − PhCHO − Bu^t, 1.2), 376 (2), 321 (7.5), 307 (26), 105 ($PhCO^+$, 27), 75 (Me_2SiOH^+, 82) and 73 (100) (Found: M^+ − Bu^t, 512.1737. $C_{26}H_{30}NO_8Si$ requires *m*/*z*, 512.1741).

(2a*R**,3*S**,5*R**,5a*S**,8a*S**,8b*S**)-*Methyl* 3,5-[(*S**)-*Benzylidenedioxy*]-5a-*cyanoacetoxymethyl*-8-*oxo*-4,5,5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **48**.—TBAF (32 mm^3 of a 1 mol dm^{-3} solution in THF, water content <5%) was added *via* syringe to a mixture of the silyl ether **47** (5.3 mg, 9.3 μmol) and powdered activated 4 Å molecular sieves (18 mg) in THF (50 mm^3) under argon. After 15 min, the suspension was diluted with CH_2Cl_2 (5 cm^3) and poured into saturated aq. NH_4Cl (5 cm^3). The aqueous layer was re-extracted with CH_2Cl_2 (4 × 10 cm^3), and the combined organic layers were dried ($MgSO_4$), and evaporated under reduced pressure. Purification of the residue by column chromatography (65% ethyl acetate–light petroleum) gave (2a*R**,3*S**,5*R**,5a*S**,-8*S**,8a*S**,8b*S**)-*methyl* 3,5-[(*S**)-*benzylidenedioxy*]-5a-*cyanoacetoxymethyl*-8-*hydroxy*-4,5,5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*-[1,8-bc]*furan*-2a-*carboxylate* (4.0 g, 94%) as an oil; ν_{max}(film)/ cm^{-1} 3428m, 3028w, 2955m, 2929m, 2261w, 1747s, 1721s, 1450m, 1388m, 1335m, 1255s, 1200s, 1108s, 981s, 761m, 736m and 702m; δ_H(500 MHz) 7.40–7.34 (5 H, m, Ph), 6.17 [1 H, s, PhC*H*$(OR)_2$], 5.85 (1 H, dd, *J* 2.1, 9.9, 6- or 7-H), 5.79 (1 H, dd, *J* 2.2, 9.9, 7- or 6-H), 4.91 (1 H, br d, *J* 4.8, 3-H), 4.49 (1 H, dd, *J* 6.2, 12.9, 8a-H), 4.45 (1 H, br d, *J* 4.5, 5-H), 4.42 (1 H, dt, *J* 6.2, 2.2, 8-H), 4.24 (1 H, d, *J* 11.5, CH_2O_2CR), 4.18 (1 H, d, *J* 11.5, CH_2O_2CR), 4.01 (1 H, d, *J* 8.5, 2-H), 3.96 (1 H, d, *J* 8.5, 2-H), 3.79 (3 H, s, CO_2Me), 3.53 (1 H, d, *J* 19.3, RO_2CCH_2CN), 3.48 (1 H, d, *J* 19.5, RO_2CCH_2CN), 3.26 (1 H, d, *J* 12.9, 8b-H), 2.94 (1 H, dt, *J* 16.1, 4.7, 4-H_{eq}), 2.49 (1 H, v br s, OH) and 1.85 (1 H, br d, *J* 16.1, 4-H_{ax}); *m*/*z* (EI) 455 (M^+, 4.9%), 454 (M^+ − H, 1.3), 437 (M^+ − H_2O, 2.1), 424 (M^+ − OMe, 0.2), 396 (M^+ − OMe − CO, 0.2), 370 (M^+ − HO_2CCH_2CN, 3.2), 349 (M^+ − PhCCO, 4.2), 319 (2), 264 (M^+ − PhCHO − HO_2CCH_2CN,

7), 250 (7.5), 232 (7.7), 146 (100), 105 ($PhCO^+$, 97) and 77 (Ph^+, 100) (Found: M^+, 455.1585. $C_{24}H_{25}NO_8$ requires M, 455.1580).

PDC (6.7 mg, 17.8 μmol) was added to a stirred mixture of the above compound (6.8 mg, 14.9 μmol) and powdered activated 4 Å molecular sieves (10 mg) in CH_2Cl_2 (0.7 cm^3). After 1.5 h, the mixture was filtered through a short pad of Florisil, which was then washed copiously with ethyl acetate (50 cm^3). The filtrate was evaporated under reduced pressure to obtain the *enone* **48** (6 mg, 89%) as a glass which required no further purification; ν_{max}(film)/cm^{-1} 3038w, 2955m, 2921m, 2258w, 1751s, 1724s, 1694s, 1590w, 1450m, 1387m, 1333m, 1252s, 1200s, 1122s, 1034m, 982s, 764m, 734m and 701m; δ_H(500 mHz) 7.38–7.27 (5 H, m, Ph), 7.01 (1 H, d, *J* 10.1, 6-H), 6.18 (1 H, d, *J* 9.9, 7-H), 6.17 [1 H, s, PhC*H*$(OR)_2$], 4.95 (1 H, br d, *J* 4.8, 3-H), 4.84 (1 H, d, *J* 14.7, 8a-H), 4.68 (1 H, br, d, *J* 4.6, 5-H), 4.44 (1 H, d, *J* 11.9, CH_2O_2CR), 4.41 (1 H, d, *J* 11.9, CH_2O_2CR), 4.06 (2 H, br s, 2-H_2), 3.82 (3 H, s, CO_2Me), 3.62 (1 H, d, *J* 14.8, 8b-H), 3.49 (2 H, s, RO_2CCH_2CN), 3.01 (1 H, dt, *J* 16.2, 4.8, 4-H_{eq}) and 1.86 (1 H, br d, *J* 16.2, 4-H_{ax}); *m/z* (EI) 453 (M^+, 16%), 452 ($M^+ - H$, 20), 422 ($M^+ - OMe$, 0.8), 394 ($M^+ - OMe - CO$, 3.4), 355 ($M^+ - CH_2O_2CCH_2CN$, 3.8), 347 ($M^+ - PhCHO$, 51), 288 (15), 262 ($M^+ - PhCHO - HO_2CCH_2CN$, 54), 105 ($PhCO^+$, 95) and 77 ($Ph^+$, 100) (Found: M^+, 453.1424. $C_{24}H_{23}NO_8$ requires M, 453.1424).

2aS,3R,5S,5aR,8S,8aR,8bR)-*Methyl* 3,5-[(R)-*Benzylidenedioxy*]-5a-(2′-*pivaloyloxyethyl*)-8-{(1″S,4″R)-4″,7″,7″-*trimethyl*-3″-*oxo*-2″-*oxabicyclo*[2.2.1]*heptan*-1″-*ylcarbonyloxy*}-4,5,5a,8,-8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **52** *and the Diastereoisomer* **51**.—(1*S*,4*R*)(−)-Camphanic acid chloride (550 mg, 2.54 mmol) was added to a solution of the alcohol **40** (491 mg, 1.01 mmol), DMAP (130 mg, 1.06 mmol) and pyridine (0.94 cm^3, 11.6 mmol) in CH_2Cl_2 (2 cm^3) under argon. The stirred solution was cooled occasionally to maintain the temperature at below 30 °C. After 21 h, the mixture was poured into saturated aq. $NaHCO_3$ (25 cm^3) and extracted with CH_2Cl_2 (4 × 50 cm^3). The combined organic layers were dried ($MgSO_4$), and evaporated under reduced pressure and the residue was purified by flash chromatography (70% diethyl ether–light petroleum) to obtain a mixture of the diastereoisomeric camphanates **51** and **52** (618 mg) as a foam. Separation of the stereoisomers by HPLC [7.5% isopropyl alcohol–light petroleum; Dynamax™ Macro HPLC Si column; flow rate 15 cm^3 min^{-1}; detection 254 nm; amount of sample per run: 40 mg, in CH_2Cl_2–IPA–light petroleum (25:5.6:69.4; 250 mm^3)] gave, in order of elution, the *camphanate* **52** (t_R 19.2 min, 287 mg, 43%) as a foam; $[\alpha]_D^{23}$ +82.2 (*c* 0.38 in $CHCl_3$); ν_{max}(film)/cm^{-1} 2964m, 1785s, 1722s, 1685w, 1478m, 1260s, 1153s, 1100s, 1062m, 987m and 734m; δ_H(500 MHz) 7.47 (2 H, br dd, *J* 1.5, 7.8, *ortho*-Ph), 7.40 (2 H, br t, *J* 7.5, *meta*-Ph), 7.34 (1 H, tt, *J* 1.4, 7.3, *para*-Ph), 6.25 (1 H, dd, *J* 0.8, 9.9, 6-H), 6.21 [1 H, s, PhC*H*$(OR)_2$], 5.90 (1 H, dd, *J* 4.6, 9.9, 7-H), 5.76 (1 H, dt, *J* 0.8, 4.9, 8-H), 4.93 (1 H, br d, *J* 4.6, 3-H), 4.59 (1 H, br d, *J* 4.6, 5-H), 4.55 (1 H, dd, *J* 5.4, 13.0, 8a-H), 4.16–4.05 (2 H, m, 2′-H_2), 3.90 (1 H, d, *J* 8.2, 2-H), 3.86 (1 H, d, *J* 8.2, 2-H), 3.76 (3 H, s, CO_2Me), 3.38 (1 H, d, *J* 12.9, 8b-H), 2.92 (1 H, dt, *J* 16.1, 4.7, 4-H_{eq}), 2.09 (1 H, br d, *J* 16.1, 4-H_{ax}), 2.03 (1 H, ddd, *J* 4.2, 10.7, 13.5, 5″- or 6″-H), 1.78–1.70 and 1.68–1.60 (4 H, m, 1′-H_2, 5″- and 6″-H), 1.45 (1 H, ddd, *J* 4.2, 9.3, 13.1, 6″- or 5″-H), 1.19 (9 H, s, Bu^t), 1.04 (3 H, s, Me), 0.97 (3 H, s, Me) and 0.84 (3 H, s, Me); *m/z* (EI) 666 (M^+, 2.3%), 468 [$M^+ - HO_2C(C_9H_{13}O_2)$, 1.5], 458 ($M^+ - PhCHO - Bu^tCO_2H$, 0.6), 362 [$M^+ - HO_2C(C_9H_{13}O_2) - PhCHO$, 1.3], 326 (3.7), 287 (3.2), 105 ($PhCO^+$, 30), 77 (Ph^+, 27) and 57 (Bu^{t+}, 100) (Found: M^+, 666.3053; C, 67.1; H, 7.25%. $C_{37}H_{46}O_{11}$ requires M, 666.3040; C, 66.65; H, 6.95%); and the *camphanate* **51** t_R 22 min, 294 mg, 44%) as a foam; $[\alpha]_D^{23}$ −56.8 (*c* 0.47 in $CHCl_3$); ν_{max}(film)/cm^{-1} 2960m, 1785s, 1749m, 1722s, 1685w, 1478m, 1260s, 1152s, 1100s, 1061s, 991m, 734m and 699m; δ_H(500 MHz) 7.46 (2 H, br dd, *J* 1.3, 8.3, *ortho*-Ph), 7.41 (2 H, br t, *J* 7.5, *meta*-Ph), 7.34 (1 H, tt, *J* 1.5, 7.2, *para*-Ph), 6.24 (1 H, dd, *J* 1.0, 9.8, 6-H), 6.20 [1 H, s, PhC*H*$(OR)_2$], 5.82 (1 H, dd, *J* 4.5, 9.8, 7-H), 5.74 (1 H, dt, *J* 1.0, 5.0, 8-H), 4.96 (1 H, br d, *J* 4.7, 3-H), 4.59 [1 H, m (obscured by 8a-H), 5-H], 4.56 (1 H, dd, *J* 5.5, 13.0, 8a-H), 4.16–4.04 (2 H, m, 2′-H_2), 3.91 (1 H, d, *J* 8.2, 2-H), 3.89 (1 H, d, *J* 8.2, 2-H), 3.76 (3 H, s, CO_2Me), 3.33 (1 H, d, *J* 13.0, 8b-H), 2.92 (1 H, dt, *J* 16.1, 4.8, 4-H_{eq}), 2.16 (1 H, ddd, *J* 4.3, 10.8, 13.5, 5″- or 6″-H), 2.05 (1 H, br d, *J* 16.1, 4-H_{ax}), 1.90 (1 H, ddd, *J* 4.6, 9.4, 13.5, 6″- or 5″-H), 1.78–1.61 (3 H, m, 1′-H_2 and 5″- or 6″-H), 1.57 (1 H ddd, *J* 4.2, 9.4, 13.2, 6″- or 5″-H), 1.19 (9 H, s, Bu^t), 1.04 (3 H, s, Me), 0.87 (3 H, s, Me) and 0.84 (3 H, s, Me); *m/z* (EI) 666 (M^+, 2.2%), 665 ($M^+ - H$, 1.7), 560 ($M^+ - PhCHO$, 0.1), 468 [$M^+ - HO_2C(C_9H_{13}O_2)$, 1.3], 458 ($M^+ - PhCHO - Bu^tCO_2H$, 0.7), 362 [$M^+ - HO_2C(C_9H_{13}O_2) - PhCHO$, 0.8], 326 (7.4), 261 (15.5), 105 ($PhCO^+$, 39), 77 (Ph^+, 28) and 57 (Bu^{t+}, 100) (Found: M^+, 666.3053).

(2aS,3R,5S,5aR,8S,8aR,8bR)-*Methyl* 3,5-[(R)-*Benzylidenedioxy*]-8-*hydroxy*-5a-(2′-*pivaloyloxyethyl*)-4,5,5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* (+)-**40** *and its Enantiomer* (−)-**40**.—Anhydrous methanol (5.9 cm^3) was added *via* syringe to a mixture of the camphanate **52** (245 mg, 0.367 mmol) and potassium carbonate (220 mg, 1.59 mmol) under argon. The suspension was stirred vigorously for 11 h, then solid NH_4Cl (250 mg, 4.67 mmol) was added. After 5 min, methanol was evaporated off under reduced pressure, and the residue was dissolved in saturated aq. NH_4Cl (12 cm^3) and extracted with CH_2Cl_2 (5 × 15 cm^3), followed by ethyl acetate (2 × 15 cm^3). The combined organic layers were dried ($MgSO_4$), and concentrated under reduced pressure. A stream of CH_2N_2/argon [generated[41] from Diazald® (50 mg)] was passed through a solution of the residue in CH_2Cl_2 (5 cm^3). When all the CH_2N_2 had been dissipated, the solution was evaporated and the residue was dried under high vacuum (0.02 mmHg) for 10 h. CH_2Cl_2 (2.5 cm^3) was added, followed by pyridine (0.425 cm^3, 5.25 mmol) and pivaloyl chloride (0.115 cm^3, 0.92 mmol). After 45 min, the solution was poured into saturated aq. NH_4Cl (20 cm^3) and extracted with CH_2Cl_2 (4 × 30 cm^3). The combined extracts were dried ($MgSO_4$), then evaporated under reduced pressure, and the residue was purified by flash chromatography (gradient elution, 60–75% diethyl ether–light petroleum) to obtain the allylic alcohol (+)-**40** (170 mg, 95%) as a foam, spectroscopically identical with the previously prepared racemic material; $[\alpha]_D^{18}$ +97.7 (*c* 1.11 in $CHCl_3$).

The diastereoisomeric camphanate **51** (103 mg, 154 μmol) was subjected to the same reaction conditions to obtain the enantiomeric allylic alcohol (−)-**40** (68 mg, 90%), identical with the previously prepared sample, except for the sign of the optical rotation; $[\alpha]_D^{20}$ −95.4 (*c* 0.81 in $CHCl_3$).

(2aS,3R,5S,5aR,8S,8aR,8bR)-*Methyl* 3,5-[(R)-*Benzylidenedioxy*]-8-tert-*butyldimethylsiloxy*-5a-(2′-*pivaloyloxyethyl*)-4,5,-5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* (+)-**53** *and its Enantiomer* (−)-**53**.—*tert*-Butyldimethylsilyl triflate (280 mm^3, 1.22 mmol) was added dropwise *via* syringe during 15 min to a stirred solution of the alcohol (+)-**40** (197 mg, 0.405 mmol) and 2,6-dimethylpyridine (2,6-lutidine) (225 mm^3, 1.93 mmol) in CH_2Cl_2 (6 cm^3) under argon at 0 °C. After 25 min, saturated aq. $NaHCO_3$ (5 cm^3) was added and the mixture was stirred for a further 5 min at 0 °C. The mixture was then poured into saturated aq. $NaHCO_3$ (5 cm^3) and extracted with CH_2Cl_2 (4 × 15 cm^3). The combined organic layers were dried ($MgSO_4$), then evaporated under reduced pressure, and

the residue was purified by flash chromatography (35% diethyl ether–light petroleum), followed by recrystallization from diethyl ether–light petroleum to obtain the *silyl ether* (+)-**53** (234 mg, 96%) as plates; $[\alpha]_D^{19}$ +69.7 (*c* 1.21 in $CHCl_3$); m.p. 141 °C; ν_{max}(film)/cm^{-1} 3015w, 2952m, 2930m, 2853m, 1722s, 1621w, 1470m, 1282m, 1252m, 1151s, 1095s, 980m, 891m, 834m and 698m; δ_H(500 MHz) 7.58–7.51 (2 H, m, Ph), 7.38–7.30 (3 H, m, Ph), 6.16 [1 H, s, PhC*H*(OR)$_2$], 5.91 (1 H, d, *J* 9.9, 6-H), 5.88 (1 H, dd, *J* 3.9, 9.9, 7-H), 4.94 (1 H, br d, *J* 4.7, 3-H), 4.50 (1 H, br d, *J* 4.6, 5-H), 4.46 (1 H, t, *J* 4.3, 8-H), 4.32 (1 H, dd, *J* 4.7, 12.6, 8a-H), 4.15–4.02 (2 H, m, 2′-H$_2$), 3.93 (1 H, d, *J* 8.1, 2-H), 3.90 (1 H, d, *J* 8.1, 2-H), 3.76 (3 H, s, CO_2Me), 3.65 (1 H, d, *J* 12.7, 8b-H), 2.90 (1 H, dt, *J* 16.0, 4.7, 4-H$_{eq}$), 2.02 (1 H, br d, *J* 16.0, 4-H$_{ax}$), 1.73 (1 H, ddd, *J* 5.8, 7.5, 14.4, 1′-H), 1.59 (1 H, dt, *J* 14.3, 7.6, 1′-H), 1.18 (9 H, s, Bu^t), 0.95 (9 H, s, Bu^t), 0.20 (3 H, s, Me) and 0.09 (3 H, s, Me); *m*/*z* (EI) 600 (M^+, 1.6%), 543 (M^+ − Bu^t, 8.4), 494 (M^+ − PhCHO, 1.2), 441 (M^+ − Bu^{t}CO$_2$H − Bu^t, 3), 437 (M^+ − PhCHO − Bu^t, 3.1), 335 (M^+ − Bu^{t}CO$_2$H − PhCHO − Bu^t, 23), 105 ($PhCO^+$, 30), 75 (Me_2SiOH^+, 65) and 57 (Bu^{t+}, 100) (Found: M^+, 600.3130; C, 65.8; H, 8.1%. $C_{33}H_{48}O_8Si$ requires M, 600.3119; C, 66.0; H, 8.05%).

The enantiomeric silyl ether (−)-**53** was prepared in the same fashion from (−)-**40** and was identical with its enantiometer in all respects except optical rotation, (−)-**53**, $[\alpha]_D^{20}$ −68.0 (*c* 0.93, $CHCl_3$).

(2a*S*,3*R*,5*S*,5a*R*,8*S*,8a*R*,8b*R*)-*Methyl* 3,5-[(*R*)-*Benzylideneidioxy*]-8-tert-*butyldimethylsiloxy*-5a-(2′-*hydroxyethyl*)-4,5,5a,8,-8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **54**.—Water (2.2 cm^3) was added to a stirred solution of the pivalate (+)-**53** (220 mg, 0.366 mmol) in ethanol (96%; 22 cm^3), followed by lithium hydroxide monohydrate (92 mg, 2.19 mmol). The mixture was heated to 60 °C for 5 h, then was cooled, and a stream of carbon dioxide was passed through the solution for 10 min. Phosphate buffer (4 cm^3; pH 5.5, prepared from saturated aq. Na_2HPO_4/H_3PO_4) was added to the opaque solution and the mixture was extracted with CH_2Cl_2 (4 × 20 cm^3), followed by ethyl acetate (1 × 20 cm^3). The combined organic layers were dried ($MgSO_4$), and evaporated under reduced pressure. A stream of CH_2N_2/argon [generated[41] from Diazald®(500 mg)] was passed through a solution of the residue in CH_2Cl_2 (5 cm^3). When all the CH_2N_2 had been dissipated, the solution was evaporated and the residue was purified by flash chromatography (gradient elution, 55–80% ethyl acetate–light petroleum) to obtain the *alcohol* **54** (172 mg, 91%) as a foam; $[\alpha]_D^{19}$ +61.4 (*c* 1.11 in $CHCl_3$); ν_{max}(film)/cm^{-1} 3433m, 3014w, 2949s, 2927m, 2889m, 2853m, 1715s, 1617w, 1469m, 1254m, 1142m, 1094s, 981m, 891m, 834m, 779m and 699m; δ_H(500 MHz) 7.58–7.50 (2 H, m, Ph), 7.38–7.30 (3 H, m, Ph), 6.15 [1 H, s, PhC*H*(OR)$_2$], 5.93 (1 H, d, *J* 10.0, 6-H), 5.87 (1 H, dd, *J* 4.5, 9.9, 7-H), 4.93 (1 H, br d, *J* 4.7, 3-H), 4.51 (1 H, br d, *J* 4.6, 5-H), 4.45 (1 H, t, *J* 4.6, 8-H), 4.34 (1 H, dd, *J* 4.7, 12.6, 8a-H), 3.93 (1 H, d, *J* 8.1, 2-H), 3.89 (1 H, d, *J* 8.1, 2-H), 3.77 (3 H, s, CO_2Me), 3.79–3.63 (2 H, m, 2′-H$_2$), 3.62 (1 H, d, *J* 12.6, 8b-H), 2.89 (1 H, dt, *J* 16.0, 4.8, 4-H$_{eq}$), 2.02 (1 H, br d, *J* 16.0, 4-H$_{ax}$), 1.69 (1 H, ddd, *J* 5.6, 7.7, 14.2, 1′-H), 1.55 (1 H, dt, *J* 14.3, 7.9, 1′-H), 1.37 (1 H, br s, OH), 0.95 (9 H, s, Bu^t), 0.20 (3 H, s, Me) and 0.09 (3 H, s, Me); *m*/*z* (EI) 516 (M^+, 1.4%), 498 (M^+ − H_2O, 0.1), 483 (M^+ − Me − H_2O, 0.3), 459 (M^+ − Bu^t, 0.4), 441 (M^+ − Bu^t − H_2O, 0.2), 427 (5.1), 410 (M^+ − PhCHO, 1.2), 353 (M^+ − PhCHO − Bu^t, 15), 335 (M^+ − PhCHO − Bu^t − H_2O, 5), 105 ($PhCO^+$, 33) and 75 (Me_2SiOH^+, 100) (Found: M^+, 516.2536; C, 65.4; H, 8.1. $C_{28}H_{40}O_7Si$ requires M, 516.2543; C, 65.1; H, 7.8%).

(2a*S*,3*R*,5*S*,5a*R*,8*S*,8a*R*,8b*R*)-*Methyl* 3,5-[(*R*)-*Benzylideneidioxy*]-8-tert-*butyldimethylsiloxy*-5a-*formylmethyl*-4,5,5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **55**.—Dess–Martin triacetoxyperiodinane reagent[35] (220 mg, 0.519 mmol) was added in one portion to a stirred solution of the alcohol **54** (164 mg, 0.317 mmol) and pyridine (220 mm^3, 2.72 mmol) in CH_2Cl_2 (8.5 cm^3) at 13 °C. The solution was allowed to warm to room temperature and was stirred for 25 min, then poured into saturated aq. $NaHCO_3/Na_2S_2O_5$ (1:1; the pH was adjusted to 7 with solid Na_2CO_3; 15 cm^3) and extracted with CH_2Cl_2 (4 × 15 cm^3). The combined organic layers were dried ($MgSO_4$), and evaporated under reduced pressure. Purification of the residue by flash chromatography (gradient elution, 65–75% diethyl ether–light petroleum) afforded the aldehyde **55** (147 mg, 90%) as a foam; $[\alpha]_D^{20}$ +65.6 (*c* 0.80 in $CHCl_3$); ν_{max}(film)/cm^{-1} 3018w, 2950m, 2926m, 2890m, 2853m, 2738w, 1716s, 1619w, 1453m, 1387m, 1255m, 1144m, 1093s, 982m, 892m, 835m and 698m; δ_H(500 MHz) 9.75 (1 H, t, *J* 2.4, CHO), 7.57–7.50 (2 H, m, Ph), 7.37–7.32 (3 H, m, Ph), 6.15 [1 H, s, PhC*H*(OR)$_2$], 6.07 (1 H, d, *J* 10.0, 6-H), 5.95 (1 H, dd, *J* 4.7, 9.8, 7-H), 4.95 (1 H, br d, *J* 4.7, 3-H), 4.53 (1 H, br d, *J* 4.6, 5-H), 4.47 (1 H, t, *J* 4.7, 8-H), 4.29 (1 H, dd, *J* 4.7, 12.6, 8a-H), 3.94 (1 H, d, *J* 8.2, 2-H$_\alpha$), 3.92 (1 H, d, *J* 8.2, 2-H$_\beta$), 3.78 (3 H, s, CO_2Me), 3.68 (1 H, d, *J* 12.6, 8b-H), 2.92 (1 H, dt, *J* 16.1, 4.7, 4-H$_{eq}$), 2.59 (1 H, dd, *J* 2.3, 16.0, C*H*$_2$CHO), 2.29 (1 H, dd, *J* 2.5, 16.0, C*H*$_2$CHO), 1.87 (1 H, d, *J* 16.1, 4-H$_{ax}$), 0.95 (9 H, s, Bu^t), 0.20 (3 H, s, Me) and 0.09 (3 H, s, Me); *m*/*z* (EI) 514 (M^+, 0.5%), 496 (M^+ − H_2O, <0.1), 471 (M^+ − C_2H_3O, 0.1), 457 (M^+ − Bu^t, 1.8), 455 (M^+ − OMe − CO, 0.1), 408 (M^+ − PhCHO, 2), 351 (M^+ − PhCHO − Bu^t, 13), 105 ($PhCO^+$, 35) and 75 (Me_2SiOH^+, 100) (Found: M^+, 514.2391; C, 65.3; H, 7.5%. $C_{28}H_{38}O_7Si$ requires M, 514.2387; C, 65.3; H, 7.4%).

(2a*S*,3*R*,5*S*,5a*S*,8*S*,8a*R*,8b*R*)-*Methyl* 3,5-[(*R*)-*Benzylideneidioxy*]-8-tert-*butyldimethylsiloxy*-5a-*formyl*-4,5,5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **57**.—*tert*-Butyldimethylsilyl triflate (50 mm^3, 259 μmol) was added dropwise *via* syringe to a stirred solution of the aldehyde **55** (44 mg, 86 μmol) and triethylamine (90 mm^3, 646 μmol) in CH_2Cl_2 (0.7 cm^3) under argon at −15 °C. After 35 min, further triethylamine (40 mm^3, 287 μmol) and *tert*-butyldimethylsilyl triflate (25 mm^3, 129 μmol) were added, and the same amounts again after 70 min. The solution was allowed to warm slowly to 5 °C during 80 min and was then poured into saturated aq. $NaHCO_3$ (10 cm^3). The mixture was extracted with CH_2Cl_2 (4 × 10 cm^3), and the combined organic layers were dried (Na_2SO_4), and evaporated under reduced pressure. Purification of the residue by flash chromatography (gradient elution, 20–80% diethyl ether–light petroleum) gave, in order of elution, the *silyl enol ether* **56** (31 mg, as a 1:1.3 *E*:*Z* mixture, contaminated with *tert*-butyldimethylsilanol) as an oil; ν_{max}(film)/cm^{-1} 3012w, 2950s, 2927s, 2885m, 2854m, 1717s, 1645m, 1468m, 1253s, 1196m, 1143s, 1095s, 1049m, 836s, 780m and 697m; δ_H(500 MHz; *E*-isomer) 7.59–7.53 (2 H, m, Ph), 7.38–7.30 (3 H, m, Ph), 6.18 [1 H, s, PhC*H*(OR)$_2$], 6.15 (1 H, d, *J* 12.2, 2′-H), 5.85 (1 H, dd, *J* 4.8, 9.7, 7-H), 5.72 (1 H, d, *J* 9.7, 6-H), 4.93 (1 H, br d, *J* 4.7, 3-H), 4.86 (1 H, d, *J* 12.1, 1′-H), 4.44 (1 H, t, *J* 4.7, 8-H), 4.32 (1 H, br d, *J* 4.7, 5-H), 4.18 (1 H, dd, *J* 4.7, 12.4, 8a-H), 3.91 (1 H, d, *J* 8.0, 2-H), 3.88 (1 H, d, *J* 8.0, 2-H), 3.74 (3 H, s, CO_2Me), 3.67 (1 H, d, *J* 12.4, 8b-H), 2.88 (1 H, dt, *J* 16.0, 4.8, 4-H$_{eq}$), 2.20 (1 H, br d, *J* 15.9, 4-H$_{ax}$), 0.95 (9 H, s, Bu^t), 0.89 (9 H, s, Bu^t), 0.21 (3 H, s, Me), 0.11 (6 H, s, 2 × Me) and 0.09 (3 H, s, Me); δ_H(500 MHz; *Z*-isomer) 7.60–7.54 (2 H, m, Ph), 7.38–7.30 (3 H, m, Ph), 6.16 (1 H, d, *J* 10.0, 6-H), 6.16 [1 H, s, PhC*H*(OR)$_2$], 6.10 (1 H, d, *J* 6.5, 2′-H), 5.73 (1 H, dd, *J* 4.9, 9.7, 7-H), 5.09 (1 H, br d, *J* 4.9, 3-H), 4.93 (1 H, br d, *J* 4.8, 5-H), 4.45 (1 H, t, *J* 4.7, 8-H), 4.34 (1 H, d, *J* 6.5, 1′-H), 4.33 (1 H, dd, *J* 4.6, 12.5, 8a-H), 3.93 (1 H, d, *J* 8.0, 2-H), 3.87 (1 H, d, *J* 8.0, 2-H), 3.75 (3 H, s, CO_2Me), 3.65 (1 H, d, *J* 12.6, 8b-H), 2.82 (1 H, dt, *J* 15.7, 4.9, 4-H$_{eq}$), 2.03 (1 H, br d, *J* 15.7, 4-H$_{ax}$), 0.96 (9 H, s, Bu^t), 0.91

(9 H, s, Bu^t), 0.20 (3 H, s, Me), 0.12 (6 H, s, 2 × Me) and 0.10 (3 H, s, Me); *m/z* (EI) 628 (M^+, 0.6%), 571 (M^+ − Bu^t, 0.3), 522 (M^+ − PhCHO, 0.5), 465 (M^+ − PhCHO − Bu^t, 6.2), 433 (0.2), 405 (0.4), 147 (100) and 75 (Me_2SiOH^+, 81) (Found: M^+, 628.3242. $C_{34}H_{52}O_7Si_2$ requires M, 628.3252); and the starting aldehyde **55** (23 mg, 52% recovery). The aldehyde was resubjected to the same reaction conditions to obtain further silyl enol ether **56** (28 mg) and the starting material **55** (2 mg recovery). The enol ether was used directly without further purification.

A trace amount of Sudan Red 7B was added to a solution of the crude silyl enol ether **56** (59 mg) in CH_2Cl_2 (7 cm^3) to give a pale pink solution. After the mixture had been cooled to −78 °C, a stream of ozone (flow rate 35 dm^3 h^{-1}; ionizing voltage 75 V) was passed through the stirred solution and the reaction was monitored by colour change of the indicator dye and by TLC. After all the starting material had been consumed (~60 min) the flask was purged with argon before a solution of triphenylphosphine (33 mg, 0.126 mmol) in CH_2Cl_2 (1 cm^3) was added and the mixture was allowed to warm slowly to room temperature during 12 h. The solvent was evaporated off under reduced pressure, the residue was purified by flash chromatography (gradient elution, 25–35% diethyl ether–light petroleum), and subsequent recrystallization from diethyl ether–light petroleum to give the *aldehyde* **57** (38 mg, 85% overall) as crystals; $[\alpha]_D^{25}$ +318.8 (*c* 1.02 in $CHCl_3$); m.p. 153 °C; ν_{max}(film)/cm^{-1} 3015w, 2950m, 2927m, 2891m, 2852m, 2735w, 1727s, 1707s, 1468m, 1396m, 1295m, 1251m, 1199m, 1136s, 1094s, 984s, 894m, 835m, 750m and 698m; δ_H(500 MHz) 9.49 (1 H, s, CHO), 7.53–7.48 (2 H, m, Ph), 7.37–7.32 (3 H, m, Ph), 6.24 (1 H, dd, *J* 4.3, 9.6, 7-H), 6.14 [1 H, s, PhC*H*(OR)$_2$], 5.63 (1 H, d, *J* 9.6, 6-H), 4.96 (1 H, br d, *J* 4.8, 3-H), 4.84 (1 H, br d, *J* 4.9, 5-H), 4.61–4.55 (2 H, m, 8- and 8a-H), 4.12 (1 H, d, *J* 8.1, 2-H), 3.94 (1 H, d, *J* 8.1, 2-H), 3.71 (3 H, s, CO_2Me), 3.67 (1 H, d, *J* 13.2, 8b-H), 2.93 (1 H, dt, *J* 16.4, 4.9, 4-H$_{eq}$), 1.62 (1 H, br d, *J* 15.9, 4-H$_{ax}$), 0.96 (9 H, s, Bu^t), 0.20 (3 H, s, Me) and 0.12 (3 H, s, Me); *m/z* (EI) 500 (M^+, 0.2%), 499 (M^+ − H, 0.5), 482 (M^+ − H_2O, 0.1), 469 (M^+ − OMe, <0.1), 443 (M^+ − Bu^t, 5.3), 394 (M^+ − PhCHO, 0.2), 379 (0.3), 363 (0.4), 337 (M^+ − PhCHO − Bu^t, 19), 319 (2.5), 105 ($PhCO^+$, 36) and 75 (Me_2SiOH^+, 100) (Found: M^+ − Bu^t, 443.1531. $C_{23}H_{27}O_7Si$ requires *m/z* 443.1526) (Found: C, 64.8; H, 7.3. $C_{27}H_{36}O_7Si$ requires C, 64.8; H, 7.25%).

(2a*S*,3*R*,5*S*,5a*R*,8*S*,8a*R*,8b*R*)-*Methyl* 3,5-[(*R*)-*Benzylidenedioxy*]-8-tert-*butyldimethylsiloxy*-5a-*cyanoacetoxymethyl*-4,5,5a,-8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **58**.—Zinc borohydride (1 cm^3 of a freshly prepared[42] 0.3 mol dm^{-3} solution in diethyl ether, 0.3 mmol) was added *via* syringe to a stirred solution of the aldehyde **57** (100.5 mg, 0.2 mmol) in THF (6.5 cm^3) at −10 °C under argon. After 30 min and 70 min further zinc borohydride (0.26 cm^3, 78 μmol) was added, and finally after 140 min one further portion (0.2 cm^3, 60 μmol). The reaction was quenched after 3 h by pouring the solution into saturated aq. $NaHCO_3$ (15 cm^3). The mixture was extracted with CH_2Cl_2 (4 × 25 cm^3), and the combined organic layers were dried ($MgSO_4$), and evaporated under reduced pressure. Residual solvent was removed under high vacuum (0.02 mmHg) for 10 min and the residue was then dissolved in anhydrous CH_2Cl_2 (3.2 cm^3) under argon. Pyridine (185 mm^3, 2.29 mmol) was added, followed by cyanoacetic acid (95 mg, 1.12 mmol) and toluene-*p*-sulfonyl chloride (125 mg, 0.66 mol). After 20 min, the yellow solution was poured into saturated aq. NH_4Cl (20 cm^3) and the aqueous layer was extracted with CH_2Cl_2 (4 × 25 cm^3). The combined organic extracts were dried ($MgSO_4$), then concentrated under reduced pressure, and the residue was purified by flash chromatography (gradient elution, 70–80% diethyl ether–light petroleum) to obtain the *cyanoacetate* **58** (112 mg, 98%) as a pale yellow foam; $[\alpha]_D^{20}$ +81.4 (*c* 1.07 in $CHCl_3$); ν_{max}(film)/cm^{-1} 3027w, 2955s, 2929s, 2856m, 2270w, 1753s, 1737s, 1473m, 1394m, 1255m, 1201m, 1095s, 984m, 894m, 835m, 763m and 700m; δ_H(270 MHz) 7.58–7.48 (2 H, m, Ph), 7.40–7.31 (3 H, m, Ph), 6.14 [1 H, s, PhC*H*(OR)$_2$], 5.96 (2 H, d, *J* 2.0, 6- and 7-H), 4.95 (1 H, br d, *J* 4.6, 3-H), 4.53 (1 H, br d, *J* 4.4, 5-H), 4.48 (1 H, dt, *J* 4.6, 2.0, 8-H), 4.39 (1 H, dd, *J* 4.6, 12.7, 8a-H), 4.26 (1 H, d, *J* 11.5, C*H*$_2$O$_2$CR), 4.21 (1 H, d, *J* 11.7, C*H*$_2$O$_2$CR), 3.96 (1 H, d, *J* 8.3, 2-H), 3.93 (1 H, d, *J* 8.3, 2-H), 3.77 (3 H, s, CO_2Me), 3.68 (1 H, d, *J* 12.7, 8b-H), 3.45 (2 H, s, RO$_2$CC*H*$_2$CN), 2.95 (1 H, dt, *J* 16.0, 4.7, 4-H$_{eq}$), 1.77 (1 H, br d, *J* 16.1, 4-H$_{ax}$), 0.95 (9 H, s, Bu^t), 0.19 (3 H, s, Me) and 0.08 (3 H, s, Me); *m/z* (EI) 569 (M^+, 0.1%), 568 (M^+ − H, 0.1), 512 (M^+ − Bu^t, 1.6), 463 (M^+ − PhCHO, 0.2), 427 (M^+ − Bu^t − HO_2CCH_2CN, 0.2), 406 (M^+ − PhCHO − Bu^t, 1.9), 376 (31), 321 (3.8), 105 ($PhCO^+$, 28) and 75 (Me_2SiOH^+, 100) (Found: M^+ − Bu^t, 512.1737. $C_{26}H_{30}NO_8Si$ requires *m/z*, 512.1741).

(2a*S*,3*R*,5*S*,5a*R*,8*S*,8a*R*,8b*R*)-*Methyl* 3,5-[(*R*)-*Benzylidenedioxy*]-5a-*cyanoacetoxymethyl*-8-*hydroxy*-4,5,5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* **59**.—TBAF (0.65 cm^3 of a 1 mol dm^{-3} solution in THF, water content <5%) was added *via* syringe to a mixture of the silyl ether **58** (108 mg, 0.19 mmol) and powdered activated 4 Å molecular sieves (400 mg) in THF (0.65 cm^3) under argon. After 105 min, further TBAF (0.32 cm^3) was added and the mixture was stirred for a further 135 min. The suspension was diluted with CH_2Cl_2 (5 cm^3) and poured into saturated aq. NH_4Cl (15 cm^3). The aqueous layer was re-extracted with CH_2Cl_2 (5 × 15 cm^3), and the combined organic layers were dried ($MgSO_4$), and evaporated under reduced pressure. Purification of the residue by column chromatography (gradient elution, 50–75% ethyl acetate–light petroleum) gave, in order of elution, the starting silyl ether **58** (4 mg, 4% recovery) and the *allyl alcohol* **59** (80 mg, 93%) as a glass; $[\alpha]_D^{20}$ +97.5 (*c*. 1.04 in $CHCl_3$); ν_{max}(film)/cm^{-1} 3515m, 2926m, 2262w, 1752s, 1730s, 1455m, 1393m, 1202s, 1107s, 1077m, 980s, 766m, 734m and 702m; δ_H(500 MHz) 7.59–7.53 (2 H, m, Ph), 7.39–7.34 (3 H, m, Ph), 6.14 [1 H, s, PhC*H*(OR)$_2$], 6.12 (1 H, dd, *J* 4.2, 9.9, 7-H), 6.04 (1 H, d, *J* 9.9, 6-H), 4.93 (1 H, br d, *J* 4.8, 3-H), 4.55–4.49 (3 H, m, 5-, 8- and 8a-H), 4.26 (1 H, d, *J* 11.6, C*H*$_2$O$_2$CR), 4.20 (1 H, d, *J* 11.6, C*H*$_2$O$_2$CR), 4.03 (1 H, d, *J* 8.4, 2-H), 4.01 (1 H, d, *J* 8.4, 2-H), 3.80 (3 H, s, CO_2Me), 3.70 (1 H, br d, *J* 12.9, 8b-H), 3.46 (2 H, s, RO$_2$CC*H*$_2$CN), 2.94 (1 H, dt, *J* 16.1, 4.7, 4-H$_{eq}$), 2.60 (1 H, d, *J* 0.8, OH) and 1.84 (1 H, br d, *J* 16.1, 4-H$_{ax}$); *m/z* (EI) 455 (M^+, 8.2%), 454 (M^+ − H, 3.1), 437 (M^+ − H_2O, 5), 423 (M^+ − HOMe, 0.4), 396 (M^+ − OMe − CO, 0.2), 370 (M^+ − HO_2CCH_2CN, 2.9), 349 (M^+ − PhCHO, 6.4), 276 (5.4), 264 (M^+ − PhCHO − HO_2CCH_2CN, 6.1), 146 (96), 105 ($PhCO^+$, 80), 91 ($C_7H_7^+$, 100) and 77 (Ph^+, 82) (Found: M^+, 455.1585. $C_{24}H_{25}NO_8$ requires M, 455.1580).

(2a*S*,3*R*,5*S*,5a*R*,8a*R*,8b*R*)-*Methyl* 3,5-[(*R*)-*Benzylidenedioxy*]-5a-*cyanoacetoxymethyl*-8-*oxo*-4,5,5a,8,8a,8b-*hexahydro*-2H,3H-*naphtho*[1,8-bc]*furan*-2a-*carboxylate* (+)-**48**.—PDC (44 mg, 117 μmol) was added to a stirred mixture of the allylic alcohol **59** (44 mg, 96.6 μmol) and powdered activated 4 Å molecular sieves (130 mg) in CH_2Cl_2 (2.2 cm^3). After 2.75 h, the mixture was filtered through a short pad of silica, which was then washed thoroughly with ethyl acetate (100 cm^3). The filtrate was evaporated under reduced pressure, and the residue was recrystallized from acetone–CH_2Cl_2 to obtain the enone (+)-**48** (38.5 mg, 88%) as a crystalline solid, spectroscopically identical with the racemic sample prepared previously; (+)-**48**, $[\alpha]_D^{20}$ +93.9 (*c* 0.25 in $CHCl_3$); m.p. 217 °C.

(2aR,4aR,5RS,8aR,9S,11R,11aS,11bR)-*Methyl* 9,11-[(R)-*Benzylidenedioxy*]-5-*cyano*-3,6-*dioxoperhydrofuro*[2′,3′,4′;4,5]-*naphtho*[8a,1-c]*pyran*-11a-*carboxylate* **49**.—LHMDS(95mm^{3}of a 1 mol dm^{-3} solution in hexanes) was added dropwise *via* syringe to a suspension of the enone (+)-**48** (34 mg, 75 μmol) in THF (2.5 cm^3) at 0 °C under argon. After 15 min, further LHMDS (10 mm^3) was added and the mixture was allowed to warm to room temperature during 15 min before further LHMDS (10 mm^3) was added. After 70 min, the solution was poured into saturated aq. NH_4Cl (3 cm^3) and extracted with CH_2Cl_2 (6 × 10 cm^3). The combined extracts were dried ($MgSO_4$) and the volatiles were evaporated off under reduced pressure. Residual hexamethyldisilazane was removed under high vacuum (0.02 mmHg) overnight to obtain the *lactone* **49** (34 mg, 100%, inseparable 5:2 mixture at C-5) as a pale yellow solid, which required no further purification; ν_{max}(film)/cm^{-1} 3035w, 2957m, 2922m, 2253w, 1732s, 1450m, 1290m, 1224m, 1197s, 1123s, 1040m, 932m, 912m, 734m and 700m; δ_H(500 MHz; major isomer only) 7.50–7.29 (5 H, m, Ph), 6.20 [1 H, s, PhC*H*(OR)$_2$], 5.05 (1 H, d, *J* 14.0, 8-H), 4.94 (1 H, br d, *J* 4.7, 11-H), 4.84 (1 H, d, *J* 14.6, 2a-H), 4.63 (1 H, br d, *J* 4.5, 9-H), 4.46 (1 H, br d, *J* 13.7, 8-H), 4.14 (1 H, d, *J* 8.8, 1-H), 4.12 (1 H, d, *J* 8.9, 1-H), 3.99 (1 H, br d, *J* 5.9, 5-H), 3.82 (3 H, s, CO_2Me), 3.15 (1 H, v br d, *J* 14.0, 4a-H), 3.12–3.01 (2 H, m, 4-H and 10-H$_{eq}$), 2.93 (1 H, d, *J* 14.4, 11b-H), 2.65 (1 H, br t, *J* 14.1, 4-H) and 1.71 (1 H, br d, *J* 16.1, 10-H$_{ax}$); *m/z* (EI) 453 (M$^+$, 0.8%), 452 (M$^+$ − H, 0.7), 396 (M$^+$ − Me − CO, 0.2), 347 (M$^+$ − PhCHO, 3), 319 (0.2), 304 (1.5), 244 (1.8), 105 (PhCO$^+$, 100), 91 ($C_7H_7^+$, 56) and 77 (Ph$^+$, 89) (Found: M$^+$, 453.1424. $C_{24}H_{23}NO_8$ requires M, 453.1424).

(2aR,4aS,5SR,7aS,8S,10R,10aS,10bR)-*Dimethyl* 5,8,10-*Trihydroxy*-3-*oxoperhydronaphtho*[1,8-bc:4,4a-c′]*difuran*-5,10a-*dicarboxylate* (−)-**50**.—Dimethyldioxirane (1.3 cm^3 of a freshly prepared[43] ~0.1 mol dm^{-3} solution in acetone) was added to a stirred solution of the α-cyano lactone **49** (40 mg, 90.4 μmol) in acetone (3.5 cm^3) at 0 °C. After 15 min, further dimethyldioxirane (0.3 cm^3) was added and the mixture was stirred for a further 7 min. The volatiles were evaporated off under reduced pressure and residual solvent was removed under high vacuum (0.02 mmHg) for 45 min. Anhydrous methanol (5 cm^3) was added to the residue *via* syringe under argon, followed by PPTS (15 mg, 59.7 μmol). The solution was stirred for 5.5 h and the solvent was then evaporated off under reduced pressure. Purification of the residue by flash chromatography (gradient elution, 90–100% ethyl acetate, then 6% methanol–CH_2Cl_2) gave the decalin fragment of azadirachtin, compound (−)-**50** (24 mg, 70%, as a 4.4:1 *S*:*R* mixture at C-5) as a foam; $[\alpha]_D^{20}$ −2.9 (5.5:1 mixture at C-5, *c* 0.49 in MeOH); the racemic compound **50** (as a 7:1 *S**:*R** mixture at C-5) could be recrystallized from ethyl acetate–methanol to obtain the *pure major* (5S*) *isomer* as prisms; m.p. 224 °C; ν_{max}(film)/cm^{-1} 3428br s, 2954m, 2918m, 2852w, 1722s, 1435m, 1272m, 1218m, 1106m, 1060s, 946w, 918w and 735m; δ_H(500 MHz; major isomer) 4.79 (1 H, d, *J* 1.1, 14.0, 2a-H), 4.45–4.40 (1 H, m, 10-H), 4.41 (1 H, d, *J* 10.0, 7-H), 4.18 (1 H, d, *J* 8.6, 1-H), 4.12 (1 H, d, *J* 8.6, 1-H), 4.00 (1 H, br dt, *J* 5.1, 2.6, 8-H), 3.86 (3 H, s, CO_2Me), 3.79–3.75 (2 H, m, 5- and 8-OH), 3.75 (3 H, s, CO_2Me), 3.65 (1 H, br d, *J* 8.0, 10-OH), 3.58 (1 H, d, *J* 10.0, 7-H), 3.32 (1 H, dd, *J* 6.8, 9.3, 4a-H), 2.79 (1 H, d, *J* 13.9, 10b-H), 2.78 (1 H, ddd, *J* 1.3, 9.3, 15.7, 4-H, 2.52 (1 H, dd, *J* 6.8, 15.8, 4-H), 2.33 (1 H, dt, *J* 15.7, 3.1, 9-H) and 1.87 (1 H, dt, *J* 15.6, 2.8, 9-H); δ_H(500 MHz; minor isomer; signals partially obscured by major diastereoisomer; OH signals and 8-H not detected) 4.81 (1 H, dd, *J* 1.2, 14.0, 2a-H), 4.60 (1 H, d, *J* 10.3, 7-H), 4.52 (1 H, v br m, 10-H), 4.17 (1 H, d, *J* 8.6, 1-H), 4.13 (1 H, d, *J* 8.6, 1-H), 3.86 (1 H, d, *J* 10.3, 7-H), 3.84 (3 H, s, CO_2Me), 3.75 (3 H, s, CO_2Me), 3.02 (1 H, dd, *J* 6.0, 12.5, 4a-H), 2.76 (1 H, d, *J* 13.9, 10b-H), 2.63 (1 H, ddd, *J* 1.2, 12.5, 14.0, 4-H), 2.41 (1 H, dd, *J* 6.0, 13.9, 4-H), 2.36 (1 H, dt, *J* 15.8, 3.2, 9-H) and 1.85 (1 H, dt, *J* 15.8, 2.9, 9-H); δ_C(125.8 MHz; major isomer only) 205.0 (1 C, s, C-3), 173.7 (1 C, s, *C*O$_2$Me), 170.5 (1 C, s, *C*O$_2$Me), 101.4 (1 C, s, C-5), 77.7 (1 C, d, C-2a), 73.6 (1 C, t, C-1), 70.6 (1 C, d, C-8 or -10), 69.0 (1 C, t, C-7), 67.2 (1 C, d, C-10 or -8), 55.5 (1 C, s, C-10a), 53.7 (1 C, q, CO$_2$*Me*), 52.4 (1 C, q, CO$_2$*Me*), 51.8 (1 C, s, C-7a), 48.7 (1 C, d, C-4a), 42.6 (1 C, d, C-10b), 37.6 (1 C, t, C-4) and 33.6 (1 C, t, C-9); *m/z* (FAB, from *m*-nitrobenzyl alcohol) 387 (MH$^+$, 18%), 369 (MH$^+$ − H_2O, 100), 351 (MH$^+$ − 2H_2O, 56) and 333 (MH$^+$ − 3H_2O, 16) [Found (FAB, from *m*-nitrobenzyl alcohol): MH$^+$, 387.1291. $C_{17}H_{23}O_{10}$ requires MH, 387.1291].

(2aR,4aS,5SR,7aS,8S,10R,10aS,10bR)-*Dimethyl* 8,9-[(R)-*Benzylidenedioxy*]-5-*hydroxy*-3-*oxoperhydronaphtho*[1,8-bc:4,-4a-c′]*difuran*-5,10a-*dicarboxylate* **60**.—A mixture of the triol (−)-**50** (11.4 mg, 29.5 μmol), freshly distilled benzaldehyde (0.25 cm^3, 2.46 mmol) and PPTS (11 mg, 43.8 μmol) in anhydrous benzene (4 cm^3) was heated to reflux with azeotropic removal of water (Dean–Stark) for 4.5 h. After the mixture had cooled, triethylamine (50 mm^3, 360 μmol) was added, the solution was poured into saturated aq. $NaHCO_3$ (10 cm^3), and the mixture was extracted with CH_2Cl_2 (6 × 12 cm^3). The combined organic extracts were dried ($MgSO_4$), then evaporated under reduced pressure, and the residue was purified by flash chromatography (gradient elution, 50–90% ethyl acetate–light petroleum) to obtain the *benzylidene hemiketal* **60** (10.3 mg, 74%, inseparable 3:1 *S*:*R* mixture at C-5) as an oil; ν_{max}(film)/cm^{-1} 3424m, 2953m, 2899m, 1730s, 1434m, 1292m, 1200m, 1120s, 1052s, 982m, 913m, 731s and 699m; δ_H(500 MHz, major isomer) 7.40–7.32 (5 H, m, Ph), 6.22 [1 H, s, PhC*H*(OR)$_2$], 4.88 (1 H, br d, *J* 4.8, 10-H), 4.67 (1 H, br d, *J* 14.5, 2a-H), 4.52 (1 H, br d, *J* 4.7, 8-H), 4.47 (1 H, d, *J* 10.2, 7-H), 4.08 (2 H, br s, 1-H$_2$), 3.95 (1 H, br s, OH), 3.81 (3 H, s, CO_2Me), 3.79 (3 H, s, CO_2Me), 3.70 (1 H, d, *J* 10.2, 7-H), 3.40 (1 H, d, *J* 14.6, 10b-H), 3.32 (1 H, br dd, *J* 5.3, 7.0, 4a-H), 3.00 (1 H, dt, *J* 15.9, 4.8, 9-H$_{eq}$), 2.62 [1 H, ddd, *J* 0.9 (long-range coupling to 2a-H), 5.1, 17.2, 4-H], 2.53 (1 H, dd, *J* 7.4, 17.1, 4-H) and 1.73 (1 H, br d, *J* 15.9, 9-H$_{ax}$); δ_H(500 MHz; minor isomer; signals partially obscured by major isomer; 5-OH not observed) 7.40–7.32 (5 H, m, Ph), 6.17 [1 H, s, PhC*H*(OR)$_2$], 5.03 (1 H, br d, *J* 4.9, 10-H), 4.83 (1 H, br d, *J* 4.9, 8-H), 4.80 (1 H, br d, *J* 14.5, 2a-H), 4.76 (1 H, d, *J* 10.6, 7-H), 4.12 (1 H, d, *J* 8.6, 1-H), 4.08 [1 H, m, (obscured), 1-H], 3.93 (1 H, d, *J* 10.7, 7-H), 3.81 (3 H, s, CO_2Me), 3.78 (3 H, s, CO_2Me), 3.26 (1 H, d, *J* 14.3, 10b-H), 3.18 (1 H, dd, *J* 6.1, 12.2, 4a-H), 2.96 (1 H, dt, *J* 15.9, 4.9, 9-H$_{eq}$), 2.56 (1 H, br t, *J* 13.2, 4-H), 2.43 (1 H, dd, *J* 6.1, 14.1, 4-H) and 1.60 (1 H, br d, *J* 15.9, 9-H$_{ax}$); *m/z* (CI, NH_3) 492 [(M + NH_4)$^+$, 58%], 475 (MH$^+$, 100), 460 (MH$^+$ − Me, 66), 457 (MH$^+$ − H_2O, 70), 443 (MH$^+$ − MeOH, 85), 415 (MH$^+$ − MeOH − CO, 19), 369 (MH$^+$ − PhCHO, 1.7), 351 (MH$^+$ − PhCHO − H_2O, 2) and 105 (PhCO$^+$, 13) [Found (CH, NH_3): MH$^+$, 475.1604. $C_{24}H_{27}O_{10}$ requires MH, 475.1604].

(2aR,4aS,5S,7aS,8S,10R,10aS,10bR)-*Dimethyl* 8,9-[(R)-*Benzylidenedioxy*]-5-*benzyloxy*-3-*oxoperhydronaphtho*[1,8-bc:4,4a-c′]*difuran*-5,10a-*dicarboxylate* **61** *and its* C-5 *Epimer* **62**.—Benzyl bromide (50 mm^3, 420 μmol) was added *via* syringe to a stirred mixture of the hemiketal **60** (a 3:1 mixture at C-5; 10 mg, 25.9 μmol), freshly prepared silver(I) oxide (55 mg, 237 μmol) and DMF (0.5 cm^3) under argon. After 3.5 h, the mixture was diluted with CH_2Cl_2 (5 cm^3), poured into saturated extracted NH_4Cl (7 cm^3), and extracted with CH_2Cl_2 (4 × 15 cm^3). The combined extracts were dried ($MgSO_4$) and the volatiles were evaporated off under reduced press. Residual DMF was removed under high vacuum (0.02 mmHg) at 30 °C for 10 min

and the residue was purified by flash chromatography (gradient elution, 85–100% diethyl ether–light petroleum) to obtain, in order of elution, the *benzyl ether* **61** (7.2 mg, 61%) as a foam; $[\alpha]_D^{19}$ −25.5 (*c* 0.51 in $CHCl_3$); ν_{max}(film)/cm^{-1} 3030w, 2951m, 2895m, 1726s, 1450m, 1291m, 1263m, 1200m, 1121s, 1096s, 1057s, 916m, 732m and 698m; δ_H(500 MHz) 7.40–7.23 (10 H, m, Ph), 6.20 [1 H, s, PhC*H*$(OR)_2$], 4.85 (1 H, br d, *J* 4.8, 10-H), 4.58 (1 H, d, *J* 11.5, PhCH_2O), 4.46 (1 H, br d, *J* 4.7, 8-H), 4.43 (1 H, d, *J* 11.5, PhCH_2O), 4.37 (1 H, br d, *J* 14.5, 2a-H), 4.27 (1 H, d, *J* 10.2, 7-H), 4.04 (1 H, d, *J* 8.6, 1-H), 4.02 (1 H, d, *J* 8.6, 1-H), 3.73 (1 H, d, *J* 10.3, 7-H), 3.70 (3 H, s, CO_2Me), 3.68 (3 H, s, CO_2Me), 3.39 (1 H, d, *J* 14.6, 10b-H), 2.99 (1 H, dd, *J* 3.1, 7.6, 4a-H), 2.98 (1 H, dt, *J* 16.0, 4.8, 9-H_{eq}), 2.91 [1 H, ddd, *J* 0.8 (long-range coupling to 2a-H), 3.2, 17.7, 4-H], 2.59 (1 H, dd, *J* 7.5, 17.6, 4-H) and 1.72 (1 H, br d, *J* 15.8, 9-H_{ax}); δ_C(125.8 MHz) 206.2 (1 C, s, C-3), 172.8 (1 C, s, *C*O^{12}Me), 168.4 (1 C, s, *C*O_2Me), 137.3 [1 C, s, C-1(Ph)], 136.6 [1 C, s, C-1(Ph)], 129.5 (1 C, d, *para*-Ph), 128.6 (2 C, d, *ortho*- or *meta*-Ph), 128.5 (2 C, d, *ortho*- or *meta*-Ph), 127.9 (1 C, d, *para*-Ph), 127.8 (2 C, d, *ortho*- or *meta*-Ph), 126.1 (2 C, d, *ortho*- or *meta*-Ph), 105.2 (1 C, s, C-5), 93.3 [1 C, d, Ph*C*H$(OR)_2$], 76.1 (1 C, d, C-2a), 73.4 (1 C, d, C-8), 72.7 (1 C, t, C-1), 68.3 (1 C, d, C-10), 67.4 (1 C, t, C-7), 66.3 (1 C, t, PhCH_2O), 55.2 (1 C, s, C-7a or -10a), 52.8 (1 C, q, CO_2*Me*), 52.4 (1 C, q, CO_2*Me*), 50.0 (1 C, d, C-4a), 48.8 (1 C, s, C-10a or -7a), 41.3 (1 C, d, C-10b), 38.4 (1 C, t, C-4) and 24.0 (1 C, t, C-9); *m/z* (EI) 564 (M^+, 0.4%), 533 (M^+ − OMe, 0.3), 505 (M^+ − OMe − CO, 0.9), 473 (M^+ − $PhCH_2$, 2.7), 458 ($M^{+\bullet}$ − PhCHO, 1), 456 (M^+ − $HOCH_2Ph$, 2.2), 397 (M^+ − $HOCH_2Ph$ − OMe − CO, 1.3), 367 (M^+ − PhCHO − $PhCH_2$, 11.6), 349 (9.5), 105 ($PhCO^+$, 7.8) and 91 ($C_7H_7^+$, 100) (Found: M^+, 564.1995. $C_{31}H_{32}O_{10}$ requires M, 564.1996); and the C-5 *epimer* **62** (2.3 mg, 19%) as an oil; $[\alpha]_D^{19}$ +83 (*c* 0.11 in $CHCl_3$); ν_{max}(film)/cm^{-1} 3030w, 2953m, 2918m, 2849m, 1732s, 1450m, 1387m, 1280m, 1198m, 1123s, 1098s, 1065s, 983m, 735m and 698m; δ_H(500 MHz) 7.39–7.23 (10 H, m, Ph), 6.11 [1 H, s, PhC*H*$(OR)_2$], 4.83 (1 H, d, *J* 10.5, 7-H), 4.82 (1 H, br d, *J* 14.8, 2a-H), 4.79 (1 H, br d, *J* 5.0, 10-H), 4.77 (1 H, br d, *J* 4.9, 8-H), 4.66 (1 H, d, *J* 11.8, PhCH_2O), 4.35 (1 H, d, *J* 11.8, PhCH_2O), 4.09 (1 H, d, *J* 8.6, 1-H), 4.05 (1 H, d, *J* 8.6, 1-H), 3.78 (3 H, s, CO_2Me), 3.77 [1 H, m (obscured by CO_2Me), 7-H], 3.70 (3 H, s, CO_2Me), 3.33 (1 H, dd, *J* 6.5, 11.9, 4a-H), 3.26 (1 H, d, *J* 14.4, 10b-H), 2.84 (1 H, dt, *J* 15.9, 5.0, 9-H_{eq}), 2.46 (1 H, dd, *J* 6.5, 14.0, 4-H), 2.40 (1 H, v br t, *J* 12.9, 4-H) and 1.51 (1 H, br d, *J* 15.9, 9-H_{ax}); *m/z* (EI) 564 (M^+, 0.3%), 505 (M^+ − OMe − CO, 1.4), 487 (M^+ − Ph, 0.2), 473 (M^+ − $PhCH_2$, 0.2), 458 (M^+ − PhCHO, 1.4), 456 (M^+ − $HOCH_2Ph$, 1.2), 397 (M^+ − $HOCH_2Ph$ − OMe − CO, 1), 367 (M^+ − PhCHO − $PhCH_2$, 1.6), 349 (0.6), 307 (2.8), 105 ($PhCO^+$, 5.8) and 91 ($C_7H_7^+$, 100) (Found: M^+, 564.1995. $C_{31}H_{32}O_{10}$ requires M, 564.1996).

Acknowledgements

We thank the SERC, Schering Agrochemicals Ltd. for a scholarship to H. C. K., and Dr. I. K. Boddy for helpful discussions.

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Paper 2/02590F
Received 19*th May* 1992
Accepted 23*rd June* 1992