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Stereocontrol of 1,5-related stereocentres using an intermediate silyl group—the diastereoselectivity of nucleophilic attack on a double bond adjacent to a stereogenic centre carrying a silyl group

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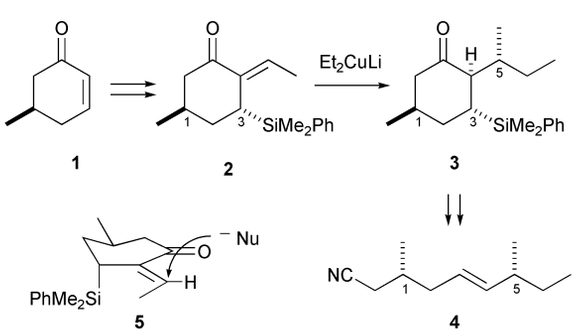
R-5-Methylcyclohex-2-enone **1** reacts successively with the phenyldimethylsilylzincate reagent and acetaldehyde to give with regiocontrol the aldols **7**, dehydration of which creates the *E*-exocyclic double bond of the α,β-unsaturated ketone **2**. Conjugate addition of the ethylcuprate reagent to this compound takes place with high (96 : 4) selectivity in favour of the *R* stereoisomer **12**, hydrolysis of which gives (2*R*,3*R*,5*S*,2′*R*)-2-(but-2′-yl)-3-dimethyl(phenyl)silyl-5-methylcyclohexanone **3**. The oxime acetate of this ketone undergoes fragmentation in the presence of trimethylsilyl trifluoromethanesulfonate to give 3*R*,7*R*,5*E*-3,7-dimethylnon-5-enonitrile **4**, in which an open-chain 1,5-stereochemical relationship is set up with a high level of stereocontrol. A similar sequence adding 4-methylpentylcuprate to the enone **2**, and fragmentation gives 3*R*,7*R*,5*E*-3,7,11-trimethyldodec-5-enonitrile **20**. Reduction and hydrogenation of this nitrile gives 3*R*,7*R*-3,7,11-trimethyldodecanal **22**, which can be converted into phytol **25**. The ketoaldehyde **29** reacts with samarium iodide to give only the alcohol **30**, in which the radical anion has attacked from the top surface, just like the cuprate reagents in their reactions with the ketone **2**.

Introduction

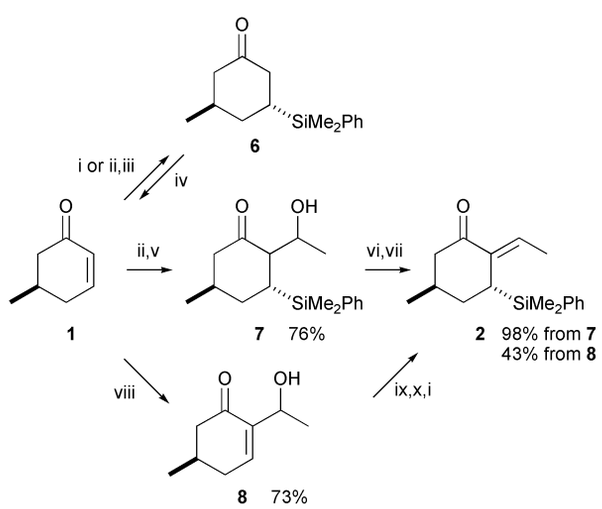
We reported in a preliminary communication that the conjugate addition of ethyl cuprate to the α,β-unsaturated ketone **2** took place with a high level of diastereocontrol in the sense anti to the silyl group in the conformation with the silyl group axial **5**.[1] We also reported that the product **3** could be converted into the nitrile **4**, showing that this reaction could be used to control the relative configuration of two stereogenic centres with an open-chain 1,5-relationship. The essence of our approach is successively to set up two 1,3-relationships, moving the stereochemistry three atoms along the chain in each of the steps **1** ⟶ **2** and **2** ⟶ **3**. By using a silyl group in the middle, we can remove the intervening functionality and stereochemistry to reveal the open-chain 1,5-relationship.



This work added to our earlier work in which a stereogenic centre carrying a silyl group induced high levels of diastereoselectivity into the electrophilic attack on an adjacent C=C double bond. Using this single idea, we had been able to control open-chain 1,2-,[2] 1,3-,[3] 1,4-[4,5] and 1,6-relationships.[6] Our solution to the control of 1,5-relationships, reported in full here, differs significantly from the methods we used for the other relationships by using nucleophilic attack on the double bond instead of electrophilic attack. Although achieving open-chain stereocontrol, it also differs by using the rigidity of a ring system.

Results and discussion

While our exploratory work was carried out with racemic 5-methylcyclohex-2-enone **1**, we describe here only the work carried out with the enantiomerically pure *R*-ketone, prepared from *R*-pulegone by a judicious selection of steps from the known route.[7] We first prepared the α,β-unsaturated ketone **2** from the ketone **1** by a conjugate addition-aldol condensation (Scheme 1). Conjugate addition of the phenyldimethylsilyl cuprate[8] or zincate[9] reagent took place with the usual high level of stereocontrol for this type of reaction,[10] which we already knew was well behaved when the nucleophile was a silyl group.[11] We isolated the same ketone **6** from both the cuprate and zincate reagents, but when we used the zincate, the intermediate enolate readily underwent a highly regioselective aldol reaction with acetaldehyde to give the β-hydroxy ketones **7** as a mixture of diastereoisomers. The cuprate reagent, although effective at



Scheme 1 *Reagents and conditions:* i, $(PhMe_2Si)_2CuLi$; ii, $PhMe_2SiZnMe_2Li$; iii, NH_4Cl, H_2O; iv, $CuBr_2$; v, MeCHO; vi, Ac_2O, DMAP, Py; vii, DBU, DMF, 100 °C; viii, Et_2AlI, MeCHO; ix, BuLi; x, $(MeO)_2CO$.

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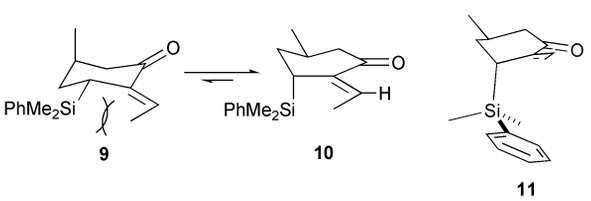
the conjugate addition, gave an enolate which was troublesome with respect to the regiochemistry in the subsequent aldol reaction. Even with the zincate, the β-hydroxy ketones **7** were sometimes contaminated with the ketone **6**, but this could be recycled by treatment with copper(II) bromide.[12] Dehydration of the aldol products **7** gave, as far as we could tell, a single α,β-unsaturated ketone **2** with the C-5 methyl and C-3 silyl groups trans to each other and the exocyclic double bond with a *Z* configuration (COSY and NOESY).

More recently, we have carried out an alternative synthesis, which might have advantages if it can be improved. Oshima's reaction of the Baylis–Hillman type,[13] using the ketone **1**, diethylaluminium iodide and acetaldehyde gave the alcohol **8**, together with 11% of the corresponding iodide. Methoxycarbonylation of the alcohol and treatment with the silylcuprate reagent gave the same unsaturated ketone **2** as before, but in inferior yield, and the acetate, mesylate and iodide gave even lower yields.

Molecular modelling calculations on the ketone **2** indicated that the conformation with the silyl group axial **10** would be lower in energy by 46.5 kJ mol^{-1} than the chair conformation with the silyl group equatorial **9**, in spite of the larger A-value for a silyl group than for a methyl group, presumably because of the $A^{1,3}$ interaction in **9**. Since the preliminary publication, we have been able to obtain a low temperature X-ray crystal structure **11**, which can be superimposed almost perfectly onto the structure calculated to have the lowest energy illustrated in the preliminary publication, except that the phenyl group and one of the methyl groups on the silicon atom have exchanged places. Whichever conformation is adopted in solution at the time of reaction, the upper surface is clear of obstruction (Fig. 1) and the lower surface is substantially hindered by the substituents on the silyl group. Provided that some unexpected electronic effect did not come into force, we expected that this steric hindrance would inspire a high level of diastereocontrol in the conjugate addition to the double bond.



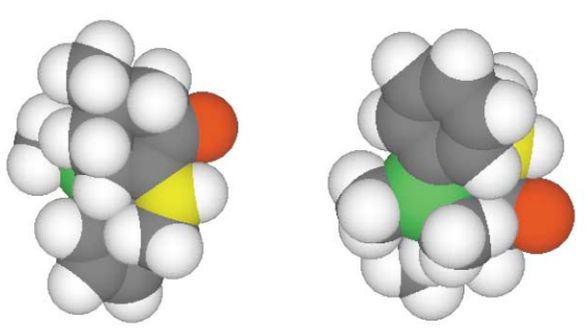
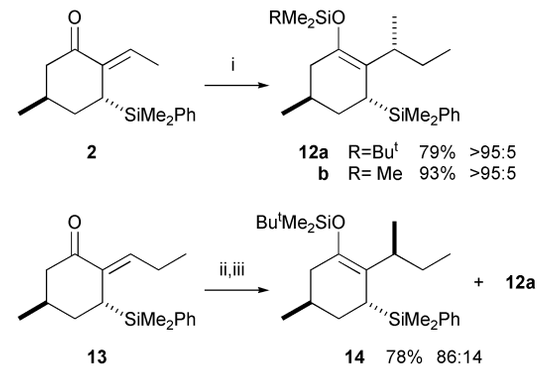


Fig. 1 Space-filling versions of the X-ray-derived structure **11** of the ketone **2** from the top (on the left) and from the bottom (on the right). The yellow atom is the β-carbon, and the green is the silicon atom.

In the event, the conjugate addition of the ethylcuprate reagent and silylation gave a silyl enol ether **12a** or **12b**, which we show below had the relative configuration illustrated (Scheme 2). The product appeared to be a single diastereoisomer (^{1}H-NMR, ^{13}C-NMR, >95 : 5), whether we added the silylating agent before the cuprate or after, whether HMPA was present or not, and whichever silylating agent we used. In practice, the reaction is best with trimethylsilyl chloride added

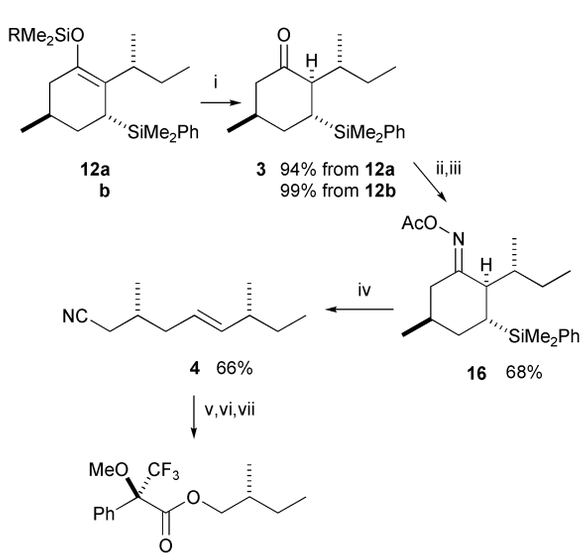


Scheme 2 *Reagents and conditions:* i, Et_2CuLi, RMe_2SiCl; ii, Me_2CuLi; iii, Bu^tMe_2SiCl, Et_3N, HMPA.

before the cuprate reagent. We carried out a complementary sequence starting from the racemic ketone **1**, trapping the zinc enolate with propionaldehyde instead of acetaldehyde to give the α,β-unsaturated ketone **13**, and adding a methylcuprate to it. This gave largely (86 : 14) the alternative stereoisomer **14**. This time we could clearly see the signals (^{1}H-NMR) of the minor isomer, which were identical to those we had already seen for the isomer **12a**. Clearly, the reaction had been stereochemically highly controlled, and either stereoisomer, **12** or **14**, could be obtained with nearly equal ease.

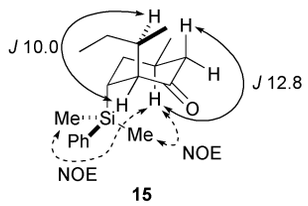
We did not vary the reaction conditions for the preparation giving largely the isomer **14**, which we had carried out in order to be sure that the diastereoisomer **14** was distinguishable from the diastereoisomer **12a**, and that we had not been misled by the appearance of only one set of signals in the NMR spectra. Since the stereoselectivity in the reaction giving the isomer **12** was insensitive to the precise conditions, we believe the lower selectivity in the formation of the isomer **14** is intrinsic. Our modelling calculations showed that the lowest-energy conformation for the ketone **13** was similar to that for the ketone **2**, except that the extra methyl group was pointing up, away from the silyl group, and hindering the top surface a little more than the top surface is hindered in the ketone **2**.

We hydrolysed the silyl enol ethers **12a** and **12b**, and obtained a single diastereoisomer of the ketone **3**, which was unaffected by treatment with sodium methoxide, suggesting that it was the thermodynamically favourable isomer (Scheme 3). The ^{1}H-NMR spectrum of this compound, together with COSY and NOESY data, indicated that it was the isomer with the C-2



Scheme 3 *Reagents and conditions:* i, HCl, H_2O, THF; ii, NH_2-OH.HCl, Py; iii, Ac_2O, Py; iv, Me_3SiOTf; v, O_3; vi, $NaBH_4$, H_2O; vii, Mosher's *R*-acid, DCC, DMAP.

and C-3 substituents trans to each other, and largely in the somewhat surprising conformation **15** with the two large groups axial.



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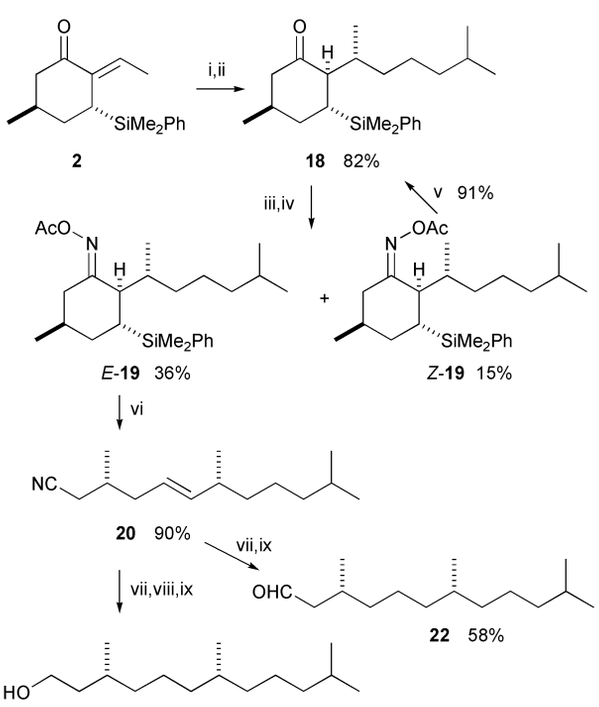
The trans configuration was confirmed when we applied the fragmentation reaction developed by Nishiyama and Itoh,[14] using the oxime acetate **16**, and obtained the alkene **4** with the double bond trans. Itoh has shown that this type of fragmentation is stereospecifically anti. The stereochemistry in the protonation step **12** ⟶ **3**, and the subsequently controlled double bond configuration, were of no consequence to us in this work, in which we were principally concerned to reveal the open chain 1,5-relationship between C-3 and C-7. Our original plan had been to use a Baeyer–Villiger reaction, but we found that the ketone **3** was completely resistant to all attempts to carry out that seemingly simple procedure. We recovered the starting material every time.

Ozonolysis of the alkene **4** and immediate reduction with sodium borohydride gave us 2-methylbutanol, from which we made the Mosher's ester **17**. The Mosher's esters of the 2-*R* and 2-*S* alcohol are both known, and we could see from the well resolved ^{1}H-NMR spectrum of our sample that it had the 2-*R* configuration, confirming our assignments. We could also, in this sample, detect 4% of the 2-*S* isomer, indicating that the diastereoselectivity in the conjugate addition step had been at least 96 : 4.

With a good method for 1,5-control in hand, we chose phytol **25** as a target which has been used before[15,16] to demonstrate the applicability of methods for 1,5-stereocontrol.[17] The synthesis used the same starting material **2**, and followed the same path (Schemes 4 and 5) except that the nucleophile was the



2 **18** 82%

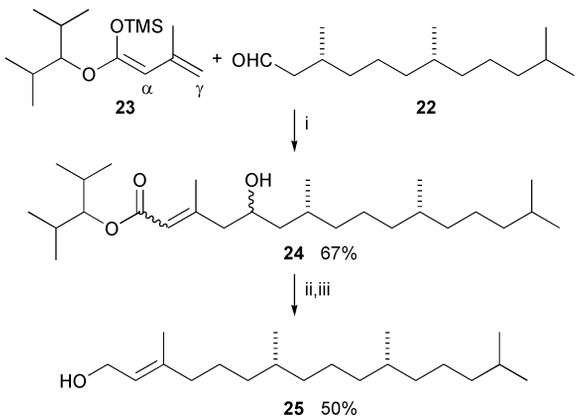
E-**19** 36% *Z*-**19** 15%

20 90%

22 58%

21 58%

Scheme 4 *Reagents and conditions:* i, $[Me_2CH(CH_2)_3]_2CuLi$, Me_3SiCl; ii, HCl, H_2O, THF; iii, $NH_2OH.HCl$, Py; iv, Ac_2O, Py; v, $TiCl_3$; vi, Me_3SiOTf; vii, DIBAL; viii, $NaBH_4$, Et_2O, MeOH; ix, H_2, Pd/C, EtOAc.



23 **22**

24 67%

25 50%

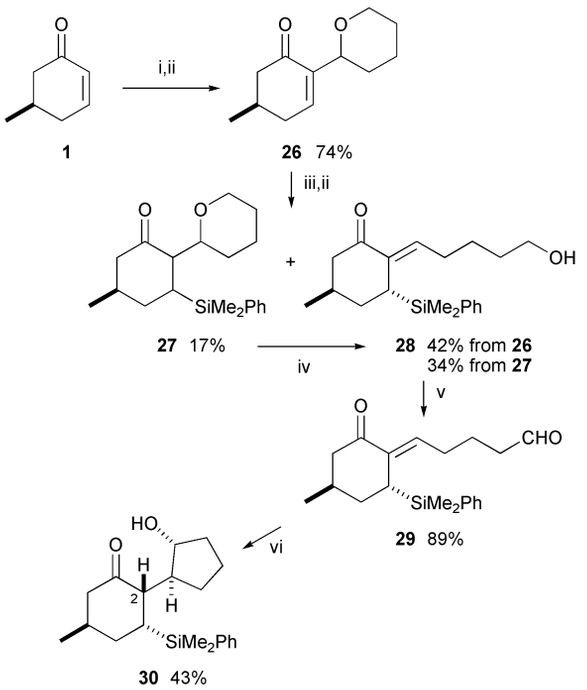
Scheme 5 *Reagents and conditions:* i, $TiCl_4$, CH_2Cl_2; ii, MsCl, Et_3N, CH_2Cl_2; iii, $LiAlH_4$, Et_2O.

isohexyl cuprate, and the product ketone **18** was worked up directly without purifying the silyl enol ether. As before, only one diastereoisomer was detectable. In this series, we were able to isolate a minor oxime acetate (17% of the mixture) *Z*-**19**. The major oxime acetate *E*-**19** gave the nitrile **20**, but the minor isomer did not undergo the fragmentation reaction. It was recovered unchanged, and could be recycled to give back the ketone **18**. Reduction of the nitrile **20** in three stages (nitrile to aldehyde, aldehyde to alcohol, and hydrogenation) gave the known alcohol **21**,[18,19] which has already been used in syntheses of α-tocopherol[20] and phytol.[16]

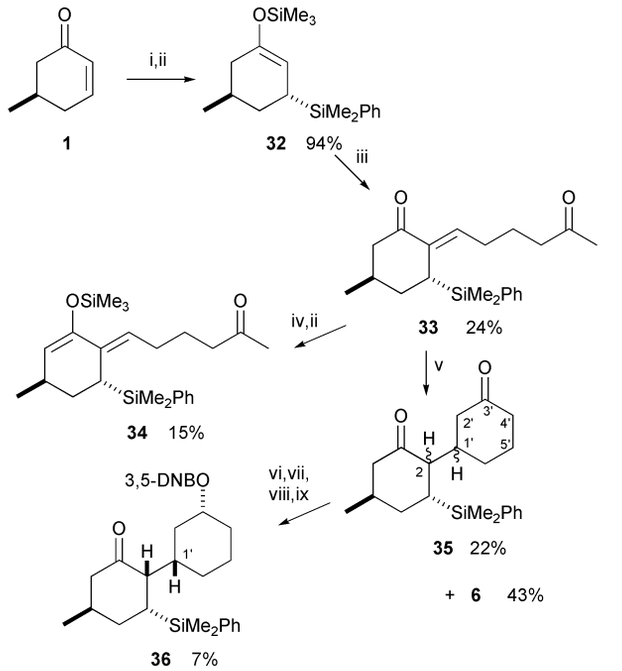
Although syntheses of tocopherol and phytol were now formally complete, we also tested another route to phytol. We had shown earlier, following Mukaiyama's lead,[21] that the silyl dienol ether **23** reacted with carbon electrophiles with high levels of γ-selectivity (d^4 reactivity),[22,23] in contrast to the corresponding lithium enolate, which reacts with high levels of α-selectivity (d^2 reactivity). Since this reaction introduces a nucleophilic 5-carbon prenyl unit, it ought to be ideal for combining with a suitable carbon electrophile derived from the 15-carbon nitrile **20**. We chose the known saturated aldehyde **22**, which we obtained by reducing the nitrile **20** in two stages. The Mukaiyama aldol reaction gave the mixture of alcohols **24** (Scheme 5), mesylation of which and reduction with lithium aluminium hydride gave phytol **25**. This synthesis has not been optimised. We have not investigated either the α:γ selectivity, which will probably have been complete, or the geometrical purity at the double bond, which will have been close to 3 : 1 (*E* : *Z*), judging by our earlier work. We simply separated the natural product and identified it from its ^{1}H- and ^{13}C-NMR spectra, which matched the known values.

We have looked at two extensions of this method for 1,5-stereocontrol. The first was to see whether an intramolecular radical attack[24] would show the same diastereoselectivity as the cuprate reagents. For this purpose we prepared the aldehyde **29** using the Baylis–Hillman-like route (Scheme 6), which took a slightly curious course by way of the tetrahydropyran **26**. Conjugate addition of the silylzincate opened the heterocyclic ring to some extent, and treatment with DBU completed the process. The aldehyde **29** reacted with samarium iodide to give largely a single alcohol **30**, in indifferent yield, but with the remainder of the mass balance containing no other simple compounds in recognisable amounts.

We expected that the four-carbon chain in the aldehyde **29** would already be oriented upwards, anti to the silyl group, just as the methyl group had been in the calculations modelling the enone **13**, and attack from above might therefore be even more selective than it had been with an external nucleophile. With only one product, however, we are not able to say more than that the reaction appears to be highly stereoselective with respect to the nucleophilic attack by the radical anion.



Scheme 6 *Reagents and conditions:* i, $TBSO(CH_2)_4CHO$, Et_2AlI; ii, NH_4Cl, H_2O; iii, $PhMe_2SiZnMe_2Li$; iv, DBU; v, $(COCl)_2$, DMSO, Et_3N; vi, SmI_2, THF.



Scheme 7 *Reagents and conditions:* i, $PhMe_2SiLiZnMe_2$; ii, Me_3SiCl; iii, $MeCO(CH_2)_3CHO$, $TiCl_4$, CH_2Cl_2; iv, LDA, THF; v, $KOBu^t$, Bu^tOH; vi, $NaBH_4$; vii, separate; viii, 3,5-dintrobenzoyl chloride, DMAP, Py; ix, TPAP, NMMO.

We identified the stereochemistry with an X-ray crystal structure of the 3,5-dinitrobenzoate (Fig. 2), which showed that it had the configuration shown. The radical anion intermediate had evidently attacked the enone system from above **31**, with the oxygen atom oriented towards the carbonyl group, and possibly coordinated to it. The unexpected feature was the stereochemistry of the protonation step at C-2, which had evidently taken place anti to the silyl group, in contrast to the results in the protonation step which had given the ketones **3** and **18** following the cuprate additions. MM2 calculations indicated that the isomer **30** in its lowest energy conformation was 18 kJ mol^{-1} lower in energy than the lowest energy conformation of its isomer at C-2, and it is therefore possible that this is a thermodynamic result.

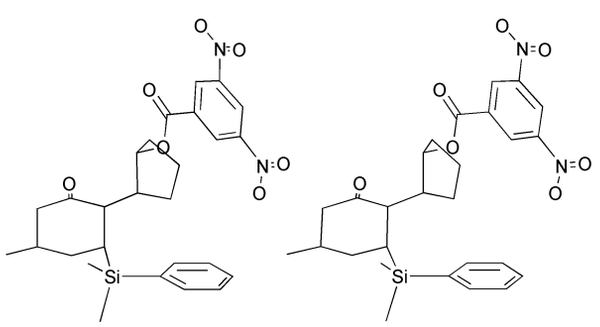
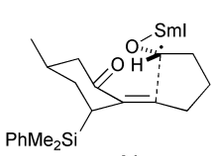


Fig. 2 Stereopair view of the 3,5-dinitrobenzoate of the alcohol **30**.



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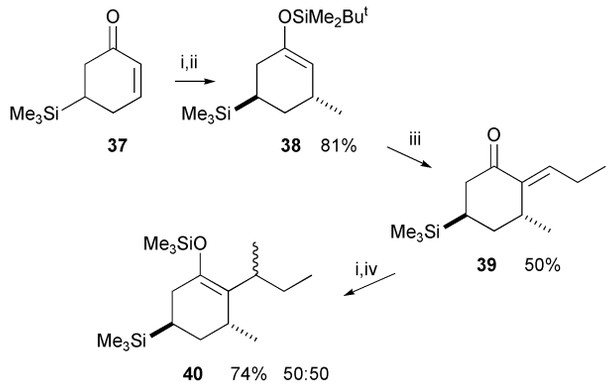
Our second extension was to investigate the possibility of an iterative sequence that would allow us to introduce a third stereocentre, with 1,5,9-relationships overall. As a model for what might be needed if the idea were to work, we prepared the ketone **33** (Scheme 7) and investigated the possibility of an intramolecular Michael reaction, in the hope that it would give a diketone **35** in which at least the stereocentre at C-1′ might have been controlled. Had this worked, a suitably constructed starting material in place of the simple ketone might allow a double bond to be introduced selectively between C-4′ and C-5′ in the newly formed six-membered ring, and a second conjugate addition-aldol reaction (or the Baylis–Hillman version), followed by another conjugate addition to the exocyclic double bond might have set up a third stereocentre. Both rings might then be cleaved in fragmentation reactions. Both might be opened at the end or the first ring might be cleaved earlier, leaving the second ring to be cleaved at the end. Since there are a number of natural products with repeating 1,5-stereocentres, this was an attractive idea.

We hoped that selective enolate formation at the methyl ketone in the diketone **33** using LDA would allow us to generate the very enolate that might undergo cyclisation under kinetic control. In the event, trapping the enolate with trimethylsilyl chloride gave the silyl enol ether **34** as the only recognisable product. Turning to thermodynamic control, potassium *tert*-butoxide in *tert*-butanol did induce cyclisation, giving at least two stereoisomeric diketones **35** in nearly equal amounts, but the major product **6** was the result of a retro-aldol reaction, or, more ominously and more likely, since we were careful to use anhydrous conditions, the result of a retro-Michael reaction from the ketone **35**. Reduction of the mixture of diketones gave three recognisably different diols in a ratio of 1 : 3.3 : 3.5, of which one, the most minor, having one axial hydroxyl group, formed a mono-3,5-dinitrobenzoate, while the other two, having only equatorial hydroxyl groups, formed bis-3,5-dinitrobenzoates. Oxidation of the free hydroxyl group in the mono-3,5-dinitrobenzoate gave a crystalline ketone **36**, which proved to have the undesirable configuration at the critical centre, C-1′. Although this was a minor product, it supplied a second piece of evidence that some level of thermodynamic control, for which there are mechanisms allowing equilibration at C-1′, had compromised the stereocontrol that we were hoping for.

Finally, we carried out one sequence to test whether a silyl group was an essential component to the stereocontrol. We prepared the ketone **39** from the racemic ketone **37**, using a Mukaiyama aldol reaction on the silyl enol ether **38** (Scheme 8).



Scheme 8 *Reagents and conditions:* i, Me_2CuLi; ii, Bu^tMe_2SiCl; iii, EtCHO, $TiCl_4$, CH_2Cl_2; iv, Me_3SiCl.

Conjugate addition of the methylcuprate reagent to the enone **39** gave almost exactly a 50 : 50 ratio of the two diastereoisomers **40**. Judging by our earlier experiences, the silyl group in the ketone **39** will now be decisively equatorial, the methyl group on C-3 will be oriented axial and down in the arbitrary absolute configuration illustrated, **41**, and the methyl group of the ethyl group will be oriented up. With the two surfaces of the double bond more or less equally hindered, this system can be expected to give a 50 : 50 ratio of diastereoisomers, supporting our analysis of the stereochemical imperatives at the exocyclic double bond in systems like these.

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Experimental

General

Infrared spectra were recorded on a Perkin-Elmer 297 infrared grating spectrophotometer or a Perkin-Elmer FT-IR 1620 infrared spectrophotometer and wave numbers measured relative to polystyrene (1603 cm^{-1}), using sodium chloride plates or sodium chloride solution cells (0.1 mm path length). ^{1}H- and ^{13}C-NMR spectra were recorded on Bruker NMR spectrometers (DRX 500, AM 400, DPX 250, AC 250, AC 200). Chemical shifts were measured relative to tetramethylsilane (δ 0.00) or chloroform (δ 7.25) as internal standards. The coupling constant J is expressed in Hertz (Hz). In ^{13}C attached proton test (APT) spectra, + denotes a signal in the same direction as the solvent signal. Mass spectra were recorded on AE1 MS 89, Kratos MS 50 or HP 5988A spectrometers and carried out by technical staff. Flash column chromatography was carried out using Merck Kieselgel 60 (230–400 mesh ASTM). Thin layer chromatography (TLC) was performed on glass plates coated to a thickness of 1 mm with Kieselgel 60 PF_{254}. Melting points were determined using a Gallenkamp melting point apparatus and stand uncorrected. Tetrahydrofuran (THF) and ether were freshly distilled from lithium aluminium hydride under argon. Dichloromethane, carbon tetrachloride, acetonitrile, methanol, light petroleum, hexane, and toluene were freshly distilled from calcium hydride under argon. Light petroleum refers to the fraction boiling in the region 40–60 °C. Other solvents and reagents where appropriate were purified before use.

Modelling calculations were carried out using the Macromodel programme (version 5.5).[25]

5*R*-5-Methylcyclohex-2-enone 1

The epoxidation of pulegone was carried out by the procedure of Katsuhara,[26] giving the epoxides (96%) as a 1 : 1 diastereoisomeric mixture, as needles, mp 41–42 °C. The epoxide was converted to the sulfide by minor modification of the procedure outlined by Caine,[7] giving the crude sulfide (100%) as a yellow oil.[27] For the oxidation of the sulfide, we followed Nangia and Prasuna[28] in using sodium periodate, and obtained the sulfoxide (91%) as a viscous yellow oil. The methods of McKillop[29] and Ali and Steven[30] were also effective, but marginally less easy to scale up. Finally, the crude sulfoxide (4.85 g, 21 mmol) and calcium carbonate (2.1 g, 21 mmol) were refluxed in carbon tetrachloride (30 cm^3) for 20 h. The mixture was poured into water (20 cm^3) and extracted with dichloromethane (3 × 10 cm^3). The combined extracts were washed with brine (15 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was distilled to give the cyclohexenone **1** (1.7 g, 74%) (bp 60–70 °C at 12 mmHg); R_f(EtOAc–light petroleum, 20 : 80) 0.4; ν_{max}(film)/cm^{-1} 1681 (C=O), 1617 (C=C), 1456 and 1117; δ_H(250 MHz, $CDCl_3$) 6.90 (1 H, ddd, J 10, 5 and 2.5, C*H*=CHCO), 5.90 (1 H, dd, J 10 and 1.0, CH=C*H*CO), 2.45–2.25 (2 H, m, CH_2CH=CH), 2.25–1.80 (3 H, m, MeC*H*CH_2CO) and 1.00 (3 H, d, J 6.2, *Me*CH); δ_C(100 MHz, $CDCl_3$) 200.0+, 149.7−, 129.6−, 46.2+, 33.9+, 30.3− and 21.1−; *m*/*z* (EI) 110 (25%, M^+), 68 (100%)(Found: M^+, 110.0737. $C_7H_{10}O$ requires M, 110.0732) matching the reported values.[27,28]

Phenyldimethylsilyllithium

Lithium shot (2 g, 190 mmol) dispersed in oil was washed with dry hexane (3 × 15 cm^3) under a flow of argon and dried under reduced pressure. Dry THF (60 cm^3) and chlorodimethyl(phenyl)silane (15 cm^3, 90 mmol) were added, and the mixture was stirred at 0 °C for 6 h, and then kept at −20 °C for 20 h. The silyllithium solution was titrated before use by the standard double titration method. Approximately equal volumes (~10 cm^3) of water and 1,2-dibromoethane were taken in two separate conical flasks and silyllithium (1 cm^3) was added to each of the flasks. After stirring for 2 min, water (2 cm^3) was added to the flask containing dibromoethane and both solutions were titrated with standard hydrochloric acid (1 mol dm^{-3}) using phenolphthalein as indicator. The difference in the volumes of the acid required gives the amount of silyllithium present in the solution, and hence the concentration of the silyllithium solution.

(2*R*,3*R*,5*S*)-2-(1′-Hydroxyethyl)-3-dimethyl(phenyl)silyl-5-methylcyclohexanone 7

Dimethyl(phenyl)silyllithium (1.07 mol dm^{-3} solution in THF, 1.02 cm^3, 1.09 mmol) was added dropwise to a solution of dimethylzinc (2 mol dm^{-3} solution in toluene, 0.55 cm^3, 1.09 mmol) in THF (5 cm^3) at −78 °C and stirred for 30 min. The enone **1** (0.10 g, 0.90 mmol) in THF (2 cm^3) was added dropwise and the mixture stirred for 1 h. Acetaldehyde (0.1 cm^3, 2.27 mmol) was added to the mixture and stirred for 2 h at the same temperature. The mixture was warmed to room temperature and quenched slowly with basic saturated aqueous ammonium chloride solution (5 cm^3). The mixture was extracted with ether (3 × 5 cm^3), the combined organic layers were washed with water (10 cm^3), brine (5 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 10 : 90) to give the *alcohol* **7** (0.21 g, 76%); R_f(EtOAc–light petroleum, 2 : 8) 0.15; ν_{max} (film)/cm^{-1} 3439 (OH), 1689 (CO), 1250 (SiMe) and 1112 (SiPh); δ_H(250 MHz, $CDCl_3$) 7.55–7.30 (5 H, m, Ph), 3.95 (1 H, sept, MeC*H*OH), 2.40–1.90 (4 H, m, CH_2CO and SiCHCHCO), 1.80–1.55 (3 H, m, MeC*H*CH_2CHSi), 1.15 and 1.10 (3 H total, 2 × d, J 6.3, *Me*CHOH of two isomers), 0.95 (3 H, d, J 6.2, *Me*CHCH_2CHSi), 0.95 (3 H, d, J 6.3, *Me*CHCH_2), 0.33 (3 H, s, Si*Me*$_A$Me$_B$Ph) and 0.32 (3 H, s, SiMe$_A$*Me*$_B$Ph); δ_C($CDCl_3$) 215+, 214.9+, 137.5+, 133.7−, 129.2−, 127.9−, 68.5−, 67.5−, 57.6−, 48.9+, 48.6+, 33.1−, 32.1−, 31.8+, 31.4+, 26.2−, 23.4−, 22.5−, 21.3−, 20.4−,

−3.0−, −3.3−; *m*/*z* (EI) 135 (100, $SiMe_2Ph$)(Found: $M^+ - H_2O$, 272.1603. $C_{17}H_{24}OSi$ requires *M*, 272.1596).

(2*RS*,3*RS*,5*SR*)-2(1′-Hydroxypropyl)-3-dimethyl(phenyl)silyl-5-methylcyclohexanone

A similar preparation but using racemic ketone **1** and propionaldehyde instead of acetaldehyde gave the *alcohol* (6.93 g, 63%); R_f(EtOAc–light petroleum, 2 : 8) 0.38; ν_{max}(film)/cm^{-1} 3428 (OH), 1700 (C=O), 1249 (SiMe) and 1113 (SiPh); δ_H(250 MHz; $CDCl_3$) 7.5–7.3 (5 H, m, Ph), 3.70 (1 H, ddd, *J* 16.1, 7.7 and 3.4, C*H*OH), 2.5–1.3 (9 H, m, CH_2CO, MeC*H*CH_2CO, CH_2CHSi, CHSi, C*H*CHOH and CH_2CHOH), 0.98 (3 H, d, *J* 7, *Me*CH), 0.93 (3 H, t, *J* 7.4, *Me*CH_2), 0.30 (3 H, s, SiMe_A-Me_B), 0.29 (3 H, S, $SiMe_AMe_B$); δ_C($CDCl_3$) 214.7+, 137.5+, 133.8−, 129.2−, 127.9−, 73.6−, 55.6−, 55.4−, 48.8+, 33.2−, 28.7+, 26.1−, 21.2−, 9.7−, −2.9−, −3.3−; *m*/*z* (EI) 304 (2%, M^+) and 135 (100, $SiMe_2Ph$)(Found: M^+, 304.1853. $C_{18}H_{28}O_2Si$ requires *M*, 304.1858).

(2*R*,3*R*,5*S*)-2-(1′-Acetoxyethyl)-3-dimethyl(phenyl)silyl-5-methylcyclohexanone

Acetic anhydride (0.65 cm^3, 6.8 mmol), the alcohol **7** (1.00 g, 3.4 mmol), freshly distilled pyridine (2.2 cm^3, 27.2 mmol) and *N*,*N*-4-dimethylaminopyridine (DMAP) (0.2 g, 1.7 mmol) were stirred in dichloromethane (15 cm^3) at 0 °C for 12 h. The mixture was poured into water (10 cm^3) and extracted with dichloromethane (3 × 5 cm^3). The combined extracts were washed with hydrochloric acid (3 mol dm^{-3}, 2 × 5 cm^3), brine (15 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 10 : 90) to give the *acetate* (1.01 g, 92%); R_f(EtOAc–light petroleum, 2 : 8) 0.4; ν_{max}(film)/cm^{-1} 1737 (CO), 1710 (C=O), 1244 (SiMe) and 1113 (SiPh); δ_H(250 MHz, $CDCl_3$) 7.55–7.35 (5 H, m, Ph), 5.30 (1 H, m, MeC*H*O), 2.55–2.11 (4 H, m, CH_2CO and SiCHCHCO), 2.05 and 1.95 (3 H, 2 × s, MeCO of two isomers), 1.75–1.45 (3 H, m, MeC*H*CH_2CHSi), 1.15 and 1.05 (3 H, 2 × d, *J* 6.2 *Me*CHCO of two isomers), 0.95 (3 H, d, *J* 6.3, *Me*CHCH_2), 0.31 (3 H, s, Si$Me_A$$Me_B$Ph) and 0.29 (3 H, s, $SiMe_AMe_B$Ph); *m*/*z* (TES) (Found: M^+ + Na, 355.1694. $C_{19}H_{28}O_3SiNa$ requires *M*, 335.1705).

(3*RS*,5*SR*)-2-(1′-Methanesulfonyloxypropyl)-3-dimethyl-(phenyl)silyl-5-methylcyclohexanone

2(1′-Hydroxypropyl)-3-dimethyl(phenyl)silyl-5-methylcyclohexanone (2.5 g, 8.22 mmol), methanesulfonyl chloride (0.95 cm^3, 12.33 mmol) and triethylamine (2.5 cm^3, 24.6 mmol) in dichloromethane (20 cm^3) were kept at 0 °C for 2 h. The mixture was poured into water and extracted with dichloromethane (2 × 50 cm^3). The combined organic layers were washed with water (50 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 8 : 92) to give the *mesylate* (2.61 g, 89%) as a 2 : 1 mixture of diastereoisomers; R_f(EtOAc–light petroleum, 2 : 8) 0.41; ν_{max}(film)/cm^{-1} 1707 (C=O), 1376 (O–SO_2), 1250 (SiMe) and 1115 (SiPh); δ_H(250 MHz; $CDCl_3$) 7.5–7.3 (5 H, m, Ph), 5.1 (1 H, dt, *J* 9.4 and 4.8, C*H*OSO_2Me), 2.96 (3 H, s, MeSO_2O), 2.71–2.28 (2 H, m, C$H_{ax}$$H_{eq}$CO and COC*H*CHSi), 2.0–1.59 (5 H, m, $CH_{ax}H_{eq}CO$, MeC*H*CH_2CHSi, CH_2CHSi and CHSi), 0.98 (3 H, d, *J* 6.2, *Me*CH), 0.82 (3 H, t, *J* 7.3, *Me*CH_2Si); distinct peaks for other isomer, 4.9 (1 H, dt, *J* 8.5 and 5.4, $CHOSO_2$), 2.91 (3 H, s, MeSO_2O), 0.98 (3 H, d, *J* 5.4, *Me*CH), 0.72 (3 H, t, *J* 7.3, *Me*CH_2), 0.32 (3 H, s, Si$Me_A$$Me_B$), 0.3 (3 H, s, $SiMe_AMe_B$); δ_C($CDCl_3$) 211.0+, 210.4+, 136.8+, 133.7−, 129.4−, 129.3−, 128.0−, 127.9−, 82.6−, 81.6−, 52.9−, 52.2−, 49.1+, 47.8+, 38.9−, 38.6−, 33.2−, 32.7−, 30.8+, 30.6+, 25.9−, 25.5+, 25.0+, 24.4−, 22.5−, 22.1−, 8.5−, 7.4−, −7.4−, −3.1−, −3.2−, −3.4−, −3.5−; *m*/*z* (EI) 367 (5%, M − Me), 286 (30, M − $MeSO_2H$) and 135 (100, $SiMe_2Ph$)-(Found: M^+ − Me, 367.1413. $C_{18}H_{27}O_4SSi$ requires *M*, 367.1399).

(5*R*)-2-(1′-Hydroxyethyl)-5-methylcyclohex-2-enone 8 and (5*R*)-2-(1′-iodoethyl)-5-methylcyclohex-2-enone

Diethylaluminium iodide (1.0 mol dm^{-3} solution in hexane, 4.1 cm^3, 4.1 mmol) was added to a solution of 5-methyl-2-cyclohexenone **1** (300 mg, 2.7 mmol) and acetaldehyde (180 mg, 4.1 mmol) in dichloromethane (15 cm^3) at 0 °C and stirred for 30 min. It was then warmed to room temperature, diluted with ether (25 cm^3), poured into water (40 cm^3), and extracted with ether (3 × 10 cm^3). The combined organic layers were washed with brine (20 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The crude mixture was chromatographed (SiO_2, EtOAc–light petroleum, 5 : 95 to 10 : 90) to give the *alcohol* **8** (324 mg, 74%); R_f(EtOAc–light petroleum, 2 : 8) 0.04; ν_{max}(film)/cm^{-1} 3422 (OH), 1666 (C=O), 1456, 1151 and 1015; δ_H(400 MHz, $CDCl_3$) 6.85 (1 H, dt, *J* 5.7 and 1.1, CH=C), 4.54 (1 H, qn, *J* 6.2, C*H*OH), 3.09 (1 H, t, *J* 6.1, CH_AH_BCH=C), 2.50–2.40 (2 H, m, CH_AH_BCO and CH_AH_BCH=C), 2.21–1.98 (2 H, m, CH_AH_BCO and C*H*Me), 1.30 (3 H, d, *J* 6.5, *Me*CHOH) and 1.03 (3 H, d, *J* 6.2, *Me*CHCH_2); δ_C(100 MHz, $CDCl_3$) 200.3, 143.7, 141.1, 65.7, 46.2, 33.4, 29.6, 21.2, and 20.4; *m*/*z* (EI) 154 (60%, M^+), 139.1 (100%, M^+ − Me), 131, 119, 111, 69 (Found: M^+, 154.0989. $C_9H_{14}O_2$ requires *M*, 154.0994); and the *iodide* (78 mg, 11%); R_f(EtOAc–light petroleum, 2 : 8) 0.4; ν_{max}(film)/cm^{-1} 1679 (C=O), 1454, 1121 and 1014; δ_H(400 MHz, $CDCl_3$) 7.1 (1 H, m, CH=C), 5.32–5.23 (1 H, m, CHI), 2.60–2.38 (2 H, m, CH_AH_BCO and CH_AH_BCH=C), 2.29–2.05 (2 H, m, CH_AH_BCO and CH_AH_BCH=C), 1.99 (3 H, d, *J* 6.4, *Me*CHI), 1.25–1.12 (1 H, m, MeC*H*CH_2) and 1.05 (3 H, d, *J* 6.6, *Me*CHCH_2); δ_C(100 MHz, $CDCl_3$) 208.8+, 145.5−, 119.5+, 45.4−, 34.4+, 30.1−, 26.2−, 21.0+ and 16.6+; *m*/*z* (EI) 137.1 (100%, M^+ − I) (Found: M^+, 264.0011. $C_9H_{13}IO$ requires *M*, 264.0011).

(5*R*)-2-(1′-Methoxycarbonyloxyethyl)-5-methylcyclohex-2-enone

n-Butyllithium (1.4 mol dm^{-3} solution in hexane, 0.56 cm^3, 0.79 mmol) was added dropwise to a stirred solution of the alcohol **8** (103 mg, 0.65 mmol) in THF (1 cm^3) at −78 °C and stirred for 30 min, then at 0 °C for another 30 min. Dimethyl carbonate (0.11 cm^3, 1.30 mmol) was added to the reaction mixture and stirring continued at 0 °C for 30 min and at room temperature for 1.5 h. It was then quenched with aqueous saturated ammonium chloride (5 cm^3) and extracted with ether (3 × 4 cm^3). The combined organic layers were washed with brine (5 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure to give the *carbonate* (133 mg, 95%); R_f(EtOAc–light petroleum, 2 : 8) 0.3; δ_H(250 MHz, $CDCl_3$) 6.56–6.51 (1 H, m, CH=), 5.05–4.97 (1 H, m, MeC*H*O), 3.77 (3 H, s, MeO), 2.54–2.40 (2 H, m, CH_2CH=) and 2.28–0.97 (9 H, series of ms and 2 × d, *Me*CHO and MeCHCH_2), which was used directly in Method B for the next step.

(3*R*,5*S*,1′*Z*)-2-Ethylidene-3-dimethyl(phenyl)silyl-5-methyl-cyclohexanone 2

Method A. Diazabicycloundecene (DBU) (0.76 g, 5.04 mmol) and the acetate (0.3 g, 0.9 mmol) were stirred in dry dimethylformamide (DMF) (5 cm^3) at 100 °C for 5 h. The mixture was cooled to room temperature, poured into water (20 cm^3), and extracted with ethyl acetate (3 × 5 cm^3). The combined extracts were washed with hydrochloric acid (3 mol dm^{-3}, 2 × 5 cm^3), brine (10 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 5 : 95) to give the enone **2** (0.24 g, 98%); R_f(EtOAc–light petroleum, 2:8) 0.55; $[a]_D$ −74.11 (*c*. 3.5 in $CHCl_3$); ν_{max}(film)/cm^{-1} 1687 (C=O), 1615 (C=C), 1251

(SiMe), 1111 (SiPh), 734 and 701; δ_H(250 MHz, $CDCl_3$) 7.50–7.30(5 H, m, Ph), 6.35 (1 H, q, *J* 7.3, C=CH), 2.66 (1 H, d, *J* 5.4, CHSi), 2.45 (1 H, dd, *J* 12.0 and 2.4, CH_AH_BCO), 2.05–1.85 (3 H, m, $MeCHCH_2$ and $MeCHCH_AH_B$), 1.6–1.45 (1 H, m, $MeCHCH_2$), 1.37 (3 H, d, *J* 7.3, C=CH*Me*), 0.9 (3 H, d, *J* 6.0, *Me*$CHCH_2$), 0.32 (3 H, s, $SiMe_AMe_BPh$) and 0.29 (3 H, s, $SiMe_AMe_BPh$); δ_C(100 MHz, $CDCl_3$) 202.5+, 139.7+, 137.6+, 133.8−, 129.2−, 129.0−, 127.8−, 48.8+, 34.4+, 29.4−, 27.4−, 22.4−, 13.7−, −2.8− and −3.1−; *m*/*z* (EI) 272 (40%, M^+), 135 (100%, $SiMe_2Ph$)(Found: M^+, 272.1605. $C_{17}H_{24}OSi$, requires *M*, 272.1596).

Method B. Copper(I) iodide (801 mg, 4.22 mmol) was dried in a round bottomed flask under vacuum and purged with argon. Dry THF (4 cm^3) was added and the flask was cooled to −20 °C. Dimethyl(phenyl)silyllithium (1.1 mol dm^{-3} solution in THF, 7.4 cm^3, 8.43 mmol) was added and stirred for 20 min at that temperature. The carbonate (300 mg, 1.41 mmol) in THF (2 cm^3) was added to the mixture at −20 °C and stirred for 1 h, during which time it was allowed to warm to room temperature. The mixture was quenched with basic saturated ammonium chloride solution (10 cm^3) and extracted with ether (3 × 5 cm^3). The combined organic layers were washed with brine (10 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The crude product was purified by column chromatography (SiO_2, EtOAc–light petroleum, 1 : 99) to give the enone **2** (169 mg, 45%), identical (TLC, ^{1}H-NMR) with the earlier sample.

Crystal data for 2. $C_{17}H_{24}OSi$, *M* = 272.45, orthorhombic, space group $P2_12_12$ (no. 18), *a* = 12.1915(3), *b* = 15.2706(6), *c* = 8.8616(3) Å, *U* = 1649.8(1) Å^3, *Z* = 4, μ(Mo–Kα) = 0.134 mm^{-1}, 13733 reflections measured at 180(2) K using an Oxford Cryosystems Cryostream cooling apparatus, 3783 unique (R_{int} = 0.035); R_1 = 0.033, wR_2 = 0.076 [$I>2\sigma(I)$]. The structure was solved with *SHELXS-97* and refined with *SHELXL-97*.[31] CCDC reference numbers 212800–212802. See http://www.rsc.org/suppdata/ob/b3/b305880h/ for crystallographic data in .cif or other electronic format.

(3*RS*,5*SR*,1′*Z*)-3-Dimethyl(phenyl)silyl-5-methyl-2-propylidenecyclohexanone 13

A similar preparation, but using 2-(1′-methanesulfonyloxypropyl)-3-dimethyl(phenyl)silyl-5-methylcyclohexanone (4.6 g, 12.66 mmol) and DBU (9.66 cm^3, 64.2 mmol) in dry toluene (40 cm^3), and refluxing for 4 h, gave the *enone* (2.07 g, 48%); R_f(EtOAc–light petroleum, 2 : 8) 0.41; ν_{max}(film)/cm^{-1} 1708 (C=O), 1616 (C=C), 1251 (SiMe) and 1114 (SiPh); δ_H(250 MHz; $CDCl_3$) 7.48–7.31 (5 H, m, Ph), 6.19 (1 H, t, *J* 6.9, C=CH), 2.63 (1 H, d, *J* 4.9, *H*C$SiMe_2Ph$), 2.43 (1 H, dd, *J* 14.1 and 2.2, $CH_{ax}H_{eq}CO$), 2.01–1.78 (3 H, m, $CH_{ax}H_{eq}CO$ and CH_2Me), 1.69–1.46 (3 H, m, MeC*H* and CH_2CHSi), 0.89 (3 H, d, *J* 5.9, *Me*CH), 0.87 (3 H, t, *J* 7.5, CH_2Me), 0.3 (3 H, s, $SiMe_AMe_B$) and 0.28 (3 H, s, $SiMe_AMe_B$); δ_C($CDCl_3$) 202.8+, 138.1+, 137.5+, 136.2−, 133.9−, 129.2−, 127.8−, 48.9+, 34.9+, 29.4−, 27.8−, 22.4−, 21.3+, 13.3−, −2.9− and −3.1−; *m*/*z* (EI) 286 (80%, M^+) and 135 ($SiMe_2Ph$)(Found: M^+, 286.1741. $C_{18}H_{26}OSi$ requires *M*, 286.1752).

(3*R*,5*S*,2′*R*)-2-(2′-Butyl)-1-*tert*-butyl(dimethyl)silyloxy-3-dimethyl(phenyl)silyl-5-methylcyclohexene 12a

tert-Butyllithium (1.7 mol dm^{-3} solution in pentane, 45 cm^3, 77.3 mmol) and ethyl iodide (3.1 cm^3, 38.6 mmol) in THF (10 cm^3) were kept at −78 °C for 2 h. This solution was then added dropwise using a cannula to a suspension of copper(I) cyanide (1.72 g, 19.3 mmol) in THF (5 cm^3) and stirred for 30 min at −78 °C. *tert*-Butylchloro(dimethyl)silane (5.8 g, 38.6 mmol) and the enone **2** (3.5 g, 12.8 mmol) in THF (5 cm^3) were added and the mixture stirred for 1 h. Triethylamine (78 cm^3, 77.3 mmol) was added to the reaction mixture and stirred for 1 h at −78 °C, allowed to warm to room temperature, and quenched with basic saturated aqueous ammonium chloride solution. The mixture was extracted with ether (2 × 50 cm^3) and the extract was washed with water (50 cm^3), brine (50 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was chromatographed (SiO_2, light petroleum) to give the *silyl enol ether* (4.581 g, 86%); R_f(EtOAc–light petroleum, 2 : 8) 0.86; $[\alpha]_D$ +56.84 (*c*. 2.5 in $CHCl_3$); ν_{max}(film)/cm^{-1} 1649 (C=CO), 1255 ($SiMe_2$), 1110 (SiPh); δ_H(500 MHz; $CDCl_3$) 7.6–7.3 (5 H, m, Ph), 2.38 (1 H, sext, *J* 7.2, MeC*H*C=C), 2.14 (1 H, dd, *J* 15.61 and 5.5, $COCH_{ax}H_{eq}$), 1.85–1.6 (4 H, m, HCSi, $SiCHCH_{eq}H_{ax}$, MeC*H* and $COCH_{ax}H_{eq}$), 1.36–1.21 (3 H, m, $SiCHCH_{eq}H_{ax}$ and CH_2Me), 0.93 (9 H, s, ^{t}Bu), 0.83 (3 H, d, *J* 6.2, *Me*$CHCH_2CHSi$), 0.78 (3 H, d, *J* 7.1, *Me*$CHCH_2Me$), 0.69 (3 H, t, *J* 7.3, $MeCHCH_2Me$), 0.36 (3 H, s, $SiMe_AMe_BBu^t$), 0.27 (3 H, s, $SiMe_AMe_BBu^t$), 0.13 (3 H, s, $SiMe_AMe_BPh$), 0.12 (3 H, s, $SiMe_AMe_BPh$); δ_C($CDCl_3$) 141.8+, 133.8−, 128.6−, 127.7−, 120.7+, 110.9−, 39.6+, 39.0−, 34.5+, 28.8−, 28.1−, 28.0+, 26.3−, 25.7−, 22.4−, 18.4+, 17.9−, 12.8−, −1.4−, −1.6−, −2.7− and −2.8−; *m*/*z* (EI) 416 (20%, M^+), 281 (100, M − $SiMe_2Ph$) and 135 (65, $SiMe_2Ph$)(Found: M^+, 416.2922. $C_{25}H_{44}OSi_2$ requires *M*, 416.2931). The minor isomer (silyl enol ether **14**) was not detected.

(3*S*,5*R*,2′*R*)-2-(2′-Butyl)-3-dimethyl(phenyl)silyl-5-methyl-1-trimethylsilyloxycyclohexene 12b

A similar preparation, but using chlorotrimethylsilane gave the *silyl enol ether* **12b** (93%); R_f(EtOAc–light petroleum, 2 : 8) 0.72; δ_H(250 MHz, $CDCl_3$) 7.55–7.27 (5 H, m, Ph), 2.20–2.02 (1 H, m, CH_AH_BC=C), 2.19–1.57 (4 H, m, CH_AH_BC=C, $MeCHCH_2CHSi$ and $MeCHCH_2Me$), 1.52–1.16 (4 H, m, $MeCHCH_2CHSi$ and $MeCHCH_2Me$), 0.88 (3 H, d, *J* 7.0, *Me*$CHCH_2Me$), 8.02 (3 H, d, *J* 6.0, *Me*$CHCH_2CHSi$), 6.98 (3 H, t, *J* 7.4, $MeCHCH_2Me$), 0.36 (3 H, s, $SiMe_AMe_B$), 0.28 (3 H, s, $SiMe_AMe_B$) and 0.18 (9 H, s, $SiMe_3$).

(3*RS*,5*SR*,2′*SR*)-2-(2′-Butyl)-1-*tert*-butyl(dimethyl)silyloxy-3-dimethyl(phenyl)silyl-5-methylcyclohexene 14

A similar preparation, but using methyllithium (1.4 mol dm^{-3} solution in ether, 3 cm^3, 4.19 mmol), copper(I) cyanide (0.189 g, 2.08 mmol), *tert*-butylchloro(dimethyl)silane (0.417 g, 2.78 mmol) and the ketone **13** (0.4 g, 1.39 mmol), gave the *silyl enol ether* (0.456 g, 78%) as an 86:14 ratio of diastereoisomers; R_f(EtOAc–light petroleum, 2 : 8) 0.86; ν_{max}(film)/cm^{-1} 1649 (C=CO), 1255 (SiMe), 1110 (SiPh); δ_H(500 MHz; $CDCl_3$) 7.55–7.3 (5 H, m, Ph), 2.11 (1 H dd, *J* 20.7, 10.7, $COCH_{ax}H_{eq}$), 1.86 (1 H, sext, *J* 7.2, MeC*H*C=C), 1.73–1.65 (2 H, m, $MeCH_{ax}H_{eq}$ and $MeCHCH_2CHSi$), 1.60–1.50 (2 H, m, $CH_{ax}H_{eq}CHSi$ and CH_2CHSi), 1.33–1.15 (3 H, m, $CH_{ax}H_{eq}CHSi$ and $MeCH_2CHMe$), 1.02 (3 H, d, *J* 7, *Me*$CHCH_2Me$), 0.94 (9 H, s, ^{t}Bu), 0.82 (3 H, d, *J* 6.0, *Me*$CHCH_2CHSi$), 0.76 (3 H, t, *J* 7.4, $MeCHCH_2Me$), 0.36 (3 H, s, $SiMe_AMe_B{}^tBu$), 0.29 (3 H, s, $SiMe_AMe_BBu^t$), 0.14 (3 H, s, $SiMe_AMe_BPh$) and 0.13 (3 H, s, $SiMe_AMe_BPh$); δ_C($CDCl_3$) 141.8+, 140.2+, 133.7−, 128.4−, 127.5−, 120.7+, 39.6+, 39.0−, 34.5+, 29.8−, 28.1−, 28.0+, 26.3−, 22.4−, 18.4+, 17.9−, 12.8−, −1.4−, −1.6−, −2.7−, −2.8−; *m*/*z* (EI) 416 (20%, M^+), 281 (100, M − $SiMe_2Ph$) and 135 (65, $SiMe_2Ph$)(Found: M^+, 416.2922. $C_{25}H_{44}OSi_2$ requires *M*, 416.2931). The diastereoisomer ratio of 86:14 was estimated from the integrals of the signals at δ 1.02 and 0.78.

(2*R*,3*R*,5*S*,2′*R*)-2-(But-2′-yl)-3-dimethyl(phenyl)silyl-5-methylcyclohexanone 3

Hydrochloric acid (3 mol dm^{-3} in H_2O, 0.5 cm^3) and the silyl enol ether **12b** (38 mg, 0.10 mmol) were stirred in THF (1 cm^3) at room temperature for 10 h. The mixture was poured into water (5 cm^3) and extracted with ether (3 × 3 cm^3). The combined extracts were washed with saturated aqueous sodium

hydrogencarbonate solution (5 cm^3), brine (5 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 5 : 95) to give the *ketone* **3** (31 mg, 99%); R_f(EtOAc–light petroleum, 2 : 8) 0.59; $[a]_D$ +57.25 (*c*. 2.0 in $CHCl_3$); ν_{max}(film)/cm^{-1} 1706 (C=O), 1256 (SiMe) and 1110 (SiPh); δ_H(500 MHz; $CDCl_3$) 7.48–7.34 (5 H, m, Ph), 2.22 (1 H, d, *J* 13.1, C$H_{eq}$$H_{ax}$CO), 2.04 (1 H, d, *J* 10, CHCO), 2.0 (1 H, t, *J* 12.8, $CH_{eq}H_{ax}$CO), 1.9 (1 H, m, MeC*H*CH_2CO), 1.79 (1 H, m, MeC*H*CH_2Me), 1.66–1.6 (3 H, m, CHSi and CH_2CHSi), 1.47 (1 H, d sext, *J* 7.4 and 3.13, MeCHC$H_A$$H_B$Me), 1.03 (1 H, m, MeCHC$H_A$$H_B$Me), 0.94 (3 H, d, *J* 6.6, *Me*CHCH_2CO), 0.72 (3 H, d, *J* 6.5, *Me*CH-CH_2Me), 0.71 (3 H, t, *J* 7.5, MeCHCH_2*Me*), 0.29 (3 H, s, SiMe_A-Me_BPh) and 0.28 (3 H, s, Si$Me_A$$Me_B$Ph); δ_C($CDCl_3$) 214.9+, 137.9+, 133.7−, 129−, 127.7−, 55.1−, 48+, 34.2−, 33.1−, 32.2+, 25.9+, 25.6−, 22.7−, 16.2−, 10−, −3− and −3.5−; *m*/*z* (EI) 302 (20%, M^+), 245 (100, M − C_4H_9) and 135 (100, $SiMe_2$Ph)(Found: M^+, 302.2068. $C_{19}H_{30}OSi$ requires *M*, 302.2065). A similar preparation starting from the silyl enol ether **12a** gave the same product (94%).

(2*R*,3*R*,5*S*,2′*R*)-2-(2′-Butyl)-3-dimethyl(phenyl)silyl-5-methylcyclohexanone oxime

Hydroxylamine hydrochloride (0.69 g, 10 mmol) and the ketone **3** (2.0 g, 6.6 mmol) were refluxed in pyridine (1.35 cm^3) and ethanol (20 cm^3) for 12 h. The mixture was poured into water and extracted with ether (2 × 20 cm^3). The extract was washed with brine (20 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 10 : 90) to give the *oxime* (1.643 g, 78%); R_f(EtOAc–light petroleum, 3 : 7) 0.61; ν_{max}(film)/cm^{-1} 3217 (OH), 1655 (C=N), 1249 (SiMe) and 1112 (SiPh); δ_H(500 MHz; $CDCl_3$) 7.53–7.34 (5 H, m, Ph), 3.23 (1 H, d, *J* 10.5, C$H_{eq}$$H_{ax}$CN), 2.24 (1 H, d, *J* 9.6, CHCN), 1.73 (1 H, m, MeC*H*CH_2Me), 1.65 (1 H, m, MeC*H*CH_2CN), 1.59–1.43 (4 H, m, CHSi, CH_2CHSi and MeCHC$H_A$$H_B$Me), 1.25 (1 H, t, *J* 12.9, $CH_{eq}H_{ax}$CN), 1.02 (1 H, m, MeCHC$H_A$$H_B$Me), 0.93 (3 H, d, *J* 6.2, *Me*CHCH_2CN), 0.78 (3 H, t, *J* 6.8, MeCH-CH_2*Me*), 0.75 (3 H, d, *J* 7.4, *Me*CHCH_2Me), 0.33 (3 H, s, Si$Me_A$$Me_B$Ph) and 0.32 ((3 H, s, Si$Me_A$$Me_B$Ph); δ_C($CDCl_3$) 162.1+, 138.9+, 133.8−, 128.8−, 127.6−, 45.3−, 37.7+, 36.5−, 33.4−, 32.5−, 31.9−, 26.4+, 22.9−, 22.6−, 15.8−, 10.2−, −2.7− and −3.3−; *m*/*z* (EI) 260 (30%, M − C_4H_9) and 135 (100, $SiMe_2$Ph)(Found: M^+ + H, 318.2261. $C_{19}H_{31}NOSi$ requires *M* + H, 318.2253).

(2*R*,3*R*,5*S*,2′*R*)-2-(2′-Butyl)-3-dimethyl(phenyl)silyl-5-methylcyclohexanone oxime acetate 16

Acetic anhydride (0.78 cm^3, 7.65 mmol) and the oxime (1.6 g, 5.1 mmol) were stirred in pyridine (1.61 cm^3, 20.4 mmol) and dichloromethane (15 cm^3) at 0 °C for 4 h. The mixture was poured into water and extracted with ether (2 × 20 cm^3). The extract was washed with brine (20 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 10 : 90) to give the *oxime acetate* (1.593 g, 87%); R_f(EtOAc–light petroleum, 2 : 8) 0.47; ν_{max}(film)/cm^{-1} 1762 (C=O); δ_H(500 MHz; $CDCl_3$) 7.5–7.33 (5 H, m, Ph), 3.07 (1 H, d, *J* 10.3, C$H_{eq}$$H_{ax}$CN), 2.32 (1 H, d, *J* 10.3, CHCN), 2.17 (3 H, s, MeCO), 1.74 (1 H, m, MeC*H*-CH_2Me), 1.62–1.58 (3 H, m, MeC*H*CH_2CN and CH_2CHSi), 1.53–1.48 (2 H, m, CHSi, and MeCHC$H_A$$H_B$Me), 1.38 (1 H, t, *J* 12.8, $CH_{eq}H_{ax}$CN), 1.05 (1 H, sept, MeCHC$H_A$$H_B$Me), 0.92 (3 H, d, *J* 5.9, *Me*CHCH_2CN), 0.77 (3 H, t, *J* 7.5, MeCH-CH_2*Me*), 0.75 (3 H, d, *J* 6.4, *Me*CHCH_2Me)and 0.32 (6 H, s, SiMe_2Ph); δ_C($CDCl_3$) 170.1+, 169.2+, 138.1+, 133.9−, 128.9−, 127.7−, 45.1−, 39.4−, 33.7−, 31.8+, 31−, 30.9+, 22.7+, 19.9−, 16.4−, 10.3−, −2.7− and −3.1−; *m*/*z* (EI) 300 (5%, M − $MeCO_2$) and 135 (100, $SiMe_2$Ph)(Found: M^+ − OAc, 300.2153. $C_{21}H_{33}NSi$ requires *M* − OAc, 300.2147).

(3*R*,7*R*,5*E*)-3,7-Dimethylnon-5-enonitrile 4

Trimethylsilyl triflate (0.1 cm^3, 0.47 mmol) and the oxime acetate (1.51 g, 4.2 mmol) were stirred in dichloromethane (25 cm^3) at 0 °C for 4 h. The mixture was poured into water and extracted with ether (2 × 20 cm^3). The extract was washed with brine (20 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 4 : 96) to give the *nitrile* (0.459 g, 66%); R_f(EtOAc–light petroleum, 2 : 8) 0.58; $[a]_D$ −36.55 (*c*. 2.0 in $CHCl_3$); ν_{max}(film)/cm^{-1} 2246 (C≡N) and 1638 (C=C); δ_H(250 MHz; $CDCl_3$) 5.37 (1 H, dd, *J* 15.4 and 6.8, HC=C*H*CHMe), 5.26 (1 H, dt, *J* 15.4 and 6.5, *H*C=CHCHMe), 2.34 (1 H, dd, *J* 16.6 and 6.8, C$H_A$$H_B$ CN), 2.20 (1 H, dd, *J* 16.6 and 5.6, $CH_A$$H_B$ CN), 2.05 (2 H, t, *J* 6.5, CH_2CH=CH), 2.0–1.8 (2 H, m, 2 × MeC*H*), 1.34 (3 h, d, *J* 6.6, CNCH_2CH*Me*), 0.97 (3 H, d, *J* 6.7, MeCH_2CH*Me*) and 0.87 (3 H, t, *J* 7.4, *Me*CH_2CHMe); δ_C($CDCl_3$) 139.8−, 124.5−, 118.8−, 38.8+, 37.4−, 30.7−, 23.5+, 20.3−, 19.2− and 11.7−; *m*/*z* (EI) 135 (100, $SiMe_2$Ph)-(Found: M^+, 165.1517. $C_{11}H_{19}N$ requires *M*, 165.1517).

Reference sample of (2*R*,2′*RS*)-2′-methylbutyl 2-methoxy-2-phenyl-3,3,3-trifluoropropanoate

Ozone was bubbled through a solution of the racemic nitrile corresponding to the nitrile **4** (0.1 g, 0.606 mmol) in ether (25 cm^3) for 10 min at −78 °C. Sodium borohydride (0.046 g, 1.21 mmol) and water (a few drops) were added, and the mixture stirred for 1 h at room temperature. Magnesium sulfate was added to the solution and filtered. The excess ether was removed by distillation using a fractionating column, and the residue was diluted with dichloromethane (20 cm^3). (*R*)-2-Methoxy-2-phenyl-3,3,3-trifluoropropionic acid (MTPA) (0.283 g, 1.21 mmol), dicyclohexylcarbodiimide (DCC) (0.372 g, 1.81 mmol) and DMAP (8 mg, 0.06 mmol) were added and the mixture was stirred at room temperature for 16 h. The mixture was poured into water and extracted with ether (2 × 20 cm^3). The extract was washed with brine (20 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 4 : 96) to give the ester[32] (0.786 g, 79%) as a 1 : 1 mixture of diastereoisomers; R_f(EtOAc–light petroleum, 2 : 8) 0.72; ν_{max}(film)/cm^{-1} 1747 (C=O); δ_H(250 MHz; $CDCl_3$) 7.52–7.39 (5 H, m, Ph), 4.25 (1 H, dd, *J* 11 and 6, OC$H_A$$H_B$, for 2′*R*-isomer), 4.16 (1 H, d, *J* 6.1, OCH_2, for 2′*S*-isomer), 4.08 (1 H, dd, *J* 11 and 6.6, $OCH_A$$H_B$, for 2′*R*-isomer), 3.55 (3 H, s, OMe, for both isomers), 1.95–1.71 (1 H, m, MeC*H*, for both isomers), 1.41–1.13 (2 H, m, MeCH_2, for both isomers), 0.92 (3 H, d, *J* 6.7, *Me*CH, for 2′*S*-isomer), 0.91 (3 H, d, *J* 7, *Me*CH, for 2′*R*-isomer) and 0.9 (3 H, m, *Me*CH_2, for both isomers).

(2*R*,2′*R*)-2′-Methylbutyl 2-methoxy-2-phenyl-3,3,3-trifluoropropanoate 17

This compound was prepared from the nitrile **4** in the same manner as the (*R*)-MTPA ester had been prepared from racemic nitrile; δ_H(400 MHz; $CDCl_3$) 7.6–7.38 (5 H, m, Ph), 4.23 (1 H, dd, *J* 10.7 and 5.7, OC$H_A$$H_B$), 4.07 (1 H, dd, *J* 10.7 and 6.6, $OCH_A$$H_B$), 3.55 (3 H, s, OMe), 1.77 (1 H, m, MeC*H*), 1.38 (1 H, m, MeC$H_A$$CH_B$), 1.21 (1 H, m, MeC$H_ACH_B$), 0.91 (3 H, d, *J* 6.7, *Me*CH) and 0.9 (3 H, t, *J* 7.4, *Me*CH_2), together with distinctive signals for 4% of the minor diastereoisomer.

(3*R*,5*S*,2′*R*)-3-Dimethyl(phenyl)silyl-5-methyl-2-(6′-methylhept-2′-yl)-1-trimethylsilyloxycyclohexene

4-Methylpentyllithium (0.4 mol dm^{-3} solution in THF, 18.4 cm^3, 7.35 mmol, made from the bromide[33,34] and lithium wire) was added to the copper(I) bromide–dimethyl sulfide complex (756 mg, 3.68 mmol) suspended in dry THF (5 cm^3) under argon at −20 °C, and the mixture stirred for 30 min. The mixture was cooled to −78 °C and a mixture of the enone **2**

(500 mg, 1.84 mmol) and chlorotrimethylsilane (0.7 cm^3, 5.52 mmol) in ether (5 cm^3) was added dropwise. The mixture was stirred for 1 h during which time the temperature was raised to 0 °C. The mixture was quenched with saturated basic ammonium chloride solution (15 cm^3), and extracted with ether (3 × 8 cm^3). The combined organic layers were washed with brine (10 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure to give the *silyl enol ether* (670 mg, 85%); R_f(EtOAc–light petroleum, 2 : 8) 0.8; ν_{max}(film)/cm^{-1} 1706, 1590 (C=C), 1458, 1364, 1113 (SiPh) and 972; δ_H(400 MHz, $CDCl_3$) 7.55–7.29 (5 H, m, Ph), 2.10 (1 H, dd, J 15.7 and 5.0, CHSi), 1.93–1.85 (1 H, m, MeC*H*C=C), 1.78–1.40 (6 H, m, CH_2CH_2CH_2-CHMe), 0.90–0.81 (12 H, 4 overlapping ds, *Me*CHCH_2, *Me*CHC=C, *Me*CH*Me*), 0.36 (3 H, s, SiMe_AMe$_B$Ph), 0.28 (3 H, s, SiMe$_A$*Me*$_B$Ph) and 0.19 (9 H, s, $SiMe_3$); δ_C(100 MHz, $CDCl_3$) 140.5, 139.1, 132.5, 127.4, 126.4, 121.5, 38.3, 36.9, 35.7, 34.4, 33.9, 33.2, 29.7, 26.7, 25.0, 21.3, 17.8, 17.0, 0.0, −2.7 and −3.0; *m*/*z* (ESI) 453 (50%, $M^+ + Na^+$), 399 (100%)(Found: M^+ + Na, 453.2994. $C_{26}H_{46}OSi_2$, requires *M* + Na, 453.2985).

(2*R*,3*R*,5*S*,2′*R*)-2-(6′-Methylhept-2′-yl)-3-dimethyl(phenyl)-silyl-5-methylcyclohexanone 18

Hydrochloric acid (3 mol dm^{-3} in H_2O, 1.5 cm^3) and the silyl enol ether (100 mg, 0.23 mmol) were stirred in THF (3 cm^3) for 12 h at room temperature. The mixture was poured into water (5 cm^3) and extracted with ether (3 × 3 cm^3). The combined extracts were washed with saturated aqueous sodium hydrogencarbonate solution (5 cm^3), brine (5 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 5 : 95) to give the *ketone* **18** (79 mg, 96%); R_f(EtOAc–light petroleum, 2 : 8) 0.65; ν_{max}(film)/cm^{-1} 1712 (C=O), 1463, 1259 (SiMe), 1112 (SiPh), 815 and 701; δ_H(400 MHz, $CDCl_3$) 7.50–7.32 (5 H, m, Ph), 2.28–2.16 (1 H, dd, *J* 13.1 and 3.8, CH_AH$_B$CO), 2.05 (1 H, d, *J* 8.4, CHCO), 2.00 (1 H, t, *J* 12.6, CH$_A$*H*$_B$CO), 1.93–1.85 (1 H, m, MeC*H*CH$_2$CO), 1.85–1.76 (1 H, m, MeC*H*-CHCO), 1.68–1.59 (3 H, m, CH_2CHSi), 1.50–1.40 (1 H, nonet, *J* 6.5, Me_2CH), 1.19–1.00 (6 H, m, $Me_2CHCH_2CH_2$-CH_2), 0.93 (3 H, d, *J* 6.0, *Me*CHCH$_2$CO), 0.86 (6 H, d, *J* 6.5, Me_2CH), 0.73 (3 H, d, *J* 6.7, *Me*CHCHCO), 0.28 (3 H, s, SiMe_A-Me$_B$Ph) and 0.27 (3 H, s, SiMe$_A$*Me*$_B$Ph); δ_C(62.5 MHz, $CDCl_3$) 214.9+, 135.2−, 134.3+, 129.1−, 127.8−, 56.8−, 55.6−, 48.1+, 39.1+, 34.3+, 33.6−, 30.7+, 27.9−, 26.0−, 23.7+, 22.8− and 17.0−; *m*/*z* (EI) 358 (10%, M^+), 135 (100%, $SiMe_2Ph$)(Found: M^+, 258.2722. $C_{23}H_{38}OSi$ requires *M*, 358.2692).

(2*R*,3*R*,5*S*,2′*R*)-3-Dimethyl(phenyl)silyl-5-methyl-2-(6′-methyl-hept-2′-yl)cyclohexanone oxime

Hydroxylamine hydrochloride (120 mg, 1.7 mmol) and the ketone **18** (300 mg, 0.84 mmol) were refluxed in pyridine (0.27 cm^3, 3.36 mmol) and ethanol (15 cm^3) overnight. The mixture was cooled to room temperature, poured into water (20 cm^3) and extracted with ether (3 × 10 cm^3). The combined extracts were washed with brine (20 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 4 : 96) to give two isomers of the *oxime* (190 mg, 66%); R_f(EtOAc–light petroleum, 2 : 8) 0.45 and 0.38; ν_{max}(film)/cm^{-1} (faster moving, major isomer) 3195 (OH), 1726 (C=N), 1589, 1551, 1452, 1413, 1380, 1260 (SiMe) and 1094 (SiPh); δ_H(400 MHz, $CDCl_3$) 7.51–7.32 (5 H, m, Ph), 6.55 (1 H, br s, OH), 3.2 (1 H, dd, *J* 13.5 and 5.0, CH_AH$_B$CN), 2.03 (1 H, d, *J* 9.5, CHCN), 1.77 (1 H, m, MeC*H*CHCN), 1.6–1.4 (5 H, m, CH$_A$*H*$_B$CN, MeC*H*CH$_2$CN and CH_2CHSi), 1.4–1.05 (7 H, m, $Me_2CHCH_2CH_2CH_2$), 0.91 (3 H, d, *J* 6.0, *Me*CH-CH$_2$CN), 0.85 (3 H, d, *J* 3.0, CH*Me*$_A$Me$_B$), 0.83 (3 H, d, *J* 3.0, CHMe$_A$*Me*$_B$), 0.70 (3 H, d, *J* 6.7, *Me*CHCHCN) and 0.30 (6 H, s, SiMe_2Ph). The slower moving minor isomer was always obtained as a mixture with the faster moving isomer and was used for the next reaction where its acetate derivative was separated.

(2*R*,3*R*,5*S*,2′*R*)-2-(6′ Methylhept-2′-yl)-3-dimethyl(phenyl)-silyl-5-methylcyclohexanone oxime acetate 19

The mixture of oximes (38 mg, 0.10 mmol), acetic anhydride (16 μl, 0.16 mmol) were stirred in pyridine (34 μl, 0.42 mmol) and dichloromethane (4 cm^3) at 0 °C for 4 h at room temperature. The mixture was poured into water (5 cm^3) and extracted with ether (3 × 4 cm^3). The combined extracts were washed with hydrochloric acid (3 mol dm^{-3}, 5 cm^3), brine (5 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum 2 : 98) to give the *oxime acetate* *E*-**19** (24 mg, 54%); R_f(EtOAc–light petroleum 2 : 8) 0.5; ν_{max}(film)/cm^{-1} 1764 (C=O), 1629 (C=N), 1529, 1259 (SiMe), 1189, 1112 (SiPh), 920 and 701; δ_H(400 MHz, $CDCl_3$) 7.5–7.3 (5 H, m, Ph), 3.06 (1 H, dd, *J* 13.1 and 5.0, CH_AH$_B$CN), 2.31 (1 H, d, *J* 10.5, C*H*CN), 2.16 (3 H, s, MeCO), 1.8 (1 H, m, MeC*H*CHCN), 1.65–1.4 (5 H, m, CH$_A$*H*$_B$-CN, MeC*H*CH$_2$CN and CH_2CHSi), 1.4–1.05 (7 H, m, $Me_2CHCH_2CH_2CH_2$), 0.91 (3 H, d, *J* 6.3 *Me*CHCH$_2$CN), 0.85 (6 H, 2 d, *J* 6.5, Me_2CH), 0.75 (3 H, d, *J* 6.5, *Me*CHCHCN) and 0.31 (6 H, s, SiMe_2Ph); δ_C(100 MHz, $CDCl_3$) 172.8+, 171.9+, 140.9+, 136.6−, 131.7−, 130.5−, 48.3−, 42.8−, 42.1+, 37.1+, 35.3−, 34.6+, 33.9−, 33.1+, 30.8−, 28.6−, 26.6+, 25.5−, 25.4−, 22.5−, 19.9−, 0.2− and −0.3−; *m*/*z* (ESI) 438 (100%, $M^+ + Na^+$)(Found: M^+ + Na, 438.2805. $C_{25}H_{41}NO_2Si$ requires *M* + Na, 438.2804); and *Z*-**19** (10 mg, 22%); R_f(EtOAc–light petroleum 2 : 8) 0.4; ν_{max}(film)/cm^{-1} 1765 (C=O), 1658 (C=N), 1629, 1529, 1461, 1259 (SiMe), 1222, 1112 (SiPh), 920, 876 and 701; δ_H(500 MHz, $CDCl_3$) 7.48–7.32 (5 H, m, Ph), 3.1 (1 H, d, *J* 10.4, CH_AH$_B$CN), 2.49 (1 H, d, *J* 9.6, CHCN), 2.11 (3 H, s, MeCO), 1.78–1.74 (1 H, m, MeC*H*CHCN), 1.72–1.42 (5 H, m, CH$_A$*H*$_B$CN, MeC*H*CH$_2$CN and CH_2C*H*Si), 1.39–1.00 (7 H, m, $Me_2CHCH_2CH_2CH_2$), 0.94 (3 H, d, *J* 5.5, *Me*CHCH$_2$CN), 0.86–0.83 (6 H, two ds, *J* 6.6, Me_2CH), 0.70 (3 H, d, *J* 6.5, *Me*CHCHCN), 0.30 (3 H, s, SiMe_AMe$_B$Ph) and 0.28 (3 H, s, SiMe$_A$*Me*$_B$Ph); δ_C(125 MHz, $CDCl_3$) 170.4+, 168.3+, 137.9+, 133.4−, 128.8−, 127.5−, 39.6−, 38.9+, 37.1+, 33.9+, 32.0−, 31.9−, 30.3+, 27.7−, 25.1−, 23.5+, 22.5−, 22.4−, 22.2−, 19.4−, 15.4−, −3.3− and −3.4−; *m*/*z* (ESI) 438 (100%, $M^+ + Na^+$)(Found: M^+ + Na, 438.2817).

(3*R*,7*R*,5*E*)-3,7,11-Trimethyldodec-5-enonitrile 20

The oxime acetate *E*-**19** (120 mg, 0.24 mmol) and trimethylsilyl triflate (48 μl, 0.024 mmol) were stirred in dichloromethane (5 cm^3) at 0 °C for 4 h. The mixture was poured into water (10 cm^3) and extracted with ether (3 × 5 cm^3). The combined extracts were washed with brine (8 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 2 : 98) to give the *nitrile* **20** (49 mg, 90%); R_f(EtOAc–light petroleum, 2 : 8) 0.58; ν_{max}(film)/cm^{-1} 2242 (C≡N), 2128, 1640 (C=C) and 1460; δ_H(400 MHz, $CDCl_3$) 5.35 (1 H, dd, *J* 15.2 and 7.5, CH=C*H*CHMe), 5.26 (1 H, dt, *J* 15.2 and 7.0, C*H*=CHCHMe), 2.3 (1 H, dd, *J* 16.6 and 5.5, CH_ACH$_B$CN), 2.2 (1 H, dd, *J* 16.6 and 7.0, CH$_A$CH_BCN), 2.0 (3 H, m, C*H*CH=CHCH_2), 1.9 (1 H, oct, MeC*H*CH$_2$CN), 1.55–1.1 (7 H, m, $Me_2CHCH_2CH_2CH_2$), 1.06 (3 H, d, *J* 6.6, *Me*CHCH$_2$CN), 0.95 (3 H, d, *J* 6.7, *Me*CH-CH$_2$CH$_2$) and 0.85 (6 H, 2 d, *J* 6.6, Me_2CH); *m*/*z* (EI) 221 (40%, M^+)(Found: M^+, 221.2138. $C_{15}H_{27}N$ requires *M*, 221.2143).

Regeneration of the ketone 18 from the oxime acetate *Z*-19

Following Corey's procedure,[35] titanium(III) chloride (0.12 cm^3, 20% in H_2O) was added to a mixture of the oxime acetate *Z*-**19** (10 mg, 0.023 mmol) in methanol (1 cm^3) and aqueous ammonium acetate (0.12 cm^3, 3 mol dm^{-3}), and the solution kept at room temperature for 1.5 h, during which time the

colour changed from black to blue to grey. The reaction was quenched with saturated sodium hydrogencarbonate solution (3 cm^3). The mixture was poured into water (5 cm^3) and extracted with ether (3 × 5 cm^3). The combined extracts were washed with hydrochloric acid (3 mol dm^{-3}, 5 cm^3), brine (5 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 2 : 98) to give the ketone **18** (7 mg, 91%) identical (TLC, ^{1}H-NMR) with the earlier sample.

(3*R*,7*R*,5*E*)-3,7,11-Trimethyldodec-5-en-1-al

Following Mori's procedure,[36] diisobutylaluminium hydride (1.0 mol dm^{-3} in hexane, 0.85 cm^3, 0.85 mmol) and the nitrile **20** (145 mg, 0.66 mmol) were stirred in hexane (12 cm^3) at room temperature under argon for 2.5 h. Ethanol (10 cm^3) and water (6 cm^3) were added dropwise to the mixture, which was stirred for 30 min. The mixture was extracted with light petroleum (3 × 7 cm^3). The combined organic layers were washed with hydrochloric acid (3 mol dm^{-3}, 5 cm^3), water (5 cm^3), saturated aqueous sodium hydrogencarbonate solution (5 cm^3) and brine (5 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was chromatographed (SiO_2, light petroleum) to give the *aldehyde* (87 mg, 59%); R_f(EtOAc–light petroleum, 2 : 8) 0.62; ν_{max}(film)/cm^{-1} 1728 (C=O), 1653 (C=C), 1558, 1540 and 1457; δ_H(500 MHz, $CDCl_3$) 9.75 (1 H, dd, *J* 2.6 and 2.0, CHO), 5.30–5.25 (2 H, m, CH=CH), 2.43 (1 H, dddd, *J* 21.4, 16.0, 5.4 and 2.0, C$H_A$$CH_B$CHO), 2.18 (1 H, dddd, *J* 24.1, 16.0, 8.0 and 2.6, CH_ACH_BCHO), 2.13–2.00 (2 H, m, CH_2CH=CH), 1.98–1.95 (1 H, m, C*H*CH=CH), 1.55–1.45 (1 H, nonet, *J* 6.6, C*H*Me_2), 1.30–1.16 (5 H, m, C*H*Me and CH_2C$H_2$$CH_2$), 1.15–1.07 (2 H, m, C$H_2$$CH_2$$CH_2$), 0.95 (3 H, d, *J* 6.6, CH*Me*), 0.94 (3 H, d, *J* 6.7, CH*Me*) and 0.84 (6 H, d, *J* 6.6, CHMe_2); δ_C(125 MHz, $CDCl_3$) 202.7−, 139.1−, 125.1−, 50.0+, 39.6+, 38.8+, 37.0+, 36.5−, 28.3−, 27.7−, 24.8+, 22.4−, 20.6− and 19.6−; *m*/*z* (ESI) 224 (65%, M^+)(Found: M^+, 224.2135. $C_{15}H_{28}O$ requires *M*, 224.2140).

(3*R*,7*R*,5*E*)-3,7,11-Trimethyldodec-5-en-1-ol

The aldehyde (10 mg, 0.04 mmol) was stirred with sodium borohydride (15 mg, 0.405 mmol) in ether (1.5 cm^3) and methanol (1.5 cm^3) at room temperature for 15 min. The reaction was quenched with saturated aqueous ammonium chloride solution (5 cm^3) and the mixture extracted with ethyl acetate (3 × 3 cm^3). The organic layers were washed with brine (5 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 3 : 97) to give the *alcohol* (10 mg, 99%); R_f(EtOAc–light petroleum, 2 : 8) 0.3; ν_{max}(film)/cm^{-1} 3416 (br, OH), 1643 and 1104; δ_H(400 MHz, $CDCl_3$) 5.36–5.22 (2 H, m, CH=CH), 3.73–3.61 (1 H, m, CH_2OH), 2.10–1.95 (2 H, m, CH_2CH=CH), 1.90–1.81 (1 H, m, C*H*CH=CH), 1.66–1.45 (4 H, m, C$H_2$$CH_2$OH, C*H*Me and C*H*$Me_2$), 1.42–1.07 (6 H, m, $CH_2$$CH_2$$CH_2$), 0.94 (3 H, d, *J* 6.7, CH*Me*), 0.88 (3 H, d, *J* 6.6, CH*Me*) and 0.83 (6 H, d, *J* 6.6, CHMe_2). which was used directly in the next step

(3*R*,7*S*)-3,7,11-Trimethyldodecan-1-ol 21

The unsaturated alcohol (6 mg, 0.026 mmol) and palladium on charcoal (5%, ~10 mg) were stirred in ethyl acetate (1 cm^3) under hydrogen at room temperature overnight, the solid was filtered off, and the solvents removed under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 10 : 90) to give the alcohol[18,19] (6 mg, 99%); R_f(EtOAc–light petroleum, 2 : 8) 0.2; ν_{max}(film)/cm^{-1} 3618, 3422 (OH), 1641, 894 and 776; δ_H(400 MHz, $CDCl_3$) 3.72–3.61 (2 H, m, CH_2OH), 1.66–1.00 [17 H, m, CH_2CH(CH_2)$_3$CH(CH_2)$_3$CH] and 0.92–0.82 (12 H, superimposed ds, CH*Me*, CH*Me* and CHMe_2); δ_C(100 MHz, $CDCl_3$) 61.26+, 40.04+, 39.96+, 39.34+, 37.43+, 37.29+, 32.75−, 29.49−, 27.95−, 24.78+, 24.34+, 22.68−, 22.59−, 19.66− and 19.64−, matching values reported in the literature;[19] *m*/*z* 210.2 ($M^+ - H_2O$).

(3*R*,7*R*)-3,7,11-Trimethyldodecan-1-al 22

E-(3*R*,7*R*)-3,7,11-Trimethyldodec-5-en-1-al (35 mg, 0.16 mmol) and palladium on charcoal (10%, ~10 mg) were stirred in ethyl acetate (1 cm^3) under hydrogen at room temperature overnight, the solid was filtered off, and the solvent evaporated off under reduced pressure. The residue was chromatographed (SiO_2; EtOAc–light petroleum, 2 : 98) to give the saturated aldehyde[37] (34 mg, 98%); R_f(EtOAc–light petroleum, 2 : 8) 0.64; ν_{max}(film)/cm^{-1} 1731 (C=O), 1463, 1258, 1193, 968 and 803; δ_H(250 MHz, $CDCl_3$) 9.78 (1 H, dd, *J* 2.4 and 2.13, CHO), 2.40 (1 H, dddd, *J* 21.6, 15.9, 5.7 and 2.0, C$H_A$$CH_B$CHO), 2.22 (1 H, dddd, *J* 23.6, 15.9, 7.7 and 2.5, CH_ACH_BCHO), 2.15–1.90 (2 H, m, C*H*Me and C*H*Me_2), 1.60–1.01 [13 H, m, (CH_2)$_3$CH(CH_2)$_3$], 0.96 (3 H, d, *J* 6.6, CH*Me*) and 0.90–0.80 (9 H, superimposed ds, CH*Me* and CHMe_2); δ_C(62.5 MHz, $CDCl_3$) 203.1−, 51.1+, 393.3+, 37.2+, 32.7−, 28.2−, 28.0−, 24.8+, 24.3+, 22.6−, 20.0− and 19.6−.

2,4-Dimethylpent-3-yl 3-methylbut-2-enoate

3-Methylbut-2-enoic acid (5 g, 50 mmol), 2,4-dimethylpentan-3-ol (27.9 cm^3, 200 mmol) and DMAP (0.55 g, 4.5 mmol) were mixed in dichloromethane (50 cm^3) at 0 °C, and DCC (12.4 g, 60 mmol) was added and the mixture stirred for 10 min. The mixture was warmed to room temperature and stirred for 3 h. The dicyclohexylurea was filtered off through a pad of silica and Celite. The filtrate was washed with hydrochloric acid (3 mol dm^{-3}, 10 cm^3), saturated sodium hydrogencarbonate solution (10 cm^3), brine (10 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2; EtOAc–light petroleum, 1 : 99) to give the ester[23,38] (8.0 g, 81%); R_f(EtOAc–light petroleum, 2 : 8) 0.7; ν_{max}(film)/cm^{-1} 1716 (C=O) and 1650 (C=C); δ_H(250 MHz, $CDCl_3$) 5.70 (1 H, s, CH=C), 4.62 (1 H, t, *J* 6.2, CHO), 2.17 (3 H, s, *Me*$_A$$Me_B$C=CH), 1.90 (3 H, s, Me_A*Me*$_B$C=CH), 1.45–1.05 (2 H, m, two C*H*Me_2) and 0.90–0.85 (6 H, two ds, *J* 6.6, *Me*$_2$CH).

1-(2′,4′-Dimethylpent-3′-yloxy)-3-methyl-1-trimethylsilyloxybuta-1,3-diene 23

n-Butyllithium (1.45 mol dm^{-3} solution in hexane, 0.38 cm^3, 0.55 mmol) was added to a solution of freshly distilled diisopropylamine (85 µl, 0.6 mmol) at 0 °C and stirred for 20 min. The mixture was cooled to −78 °C and the ester (0.1 g, 0.5 mmol) in THF (0.1 cm^3) was added and the mixture stirred for 1 h. Chlorotrimethylsilane (0.1 cm^3, 0.86 mmol) was added slowly to the mixture and the solution warmed to room temperature over a period of 1 h. The solvent was evaporated off under reduced pressure in an inert atmosphere (nitrogen) and pentane was added to the residue. The white solid (LiCl) was filtered off and washed with pentane. The filtrate was evaporated under reduced pressure to give the silyl dienol ether[23,38] (135 mg, 99%), which was used without further purification; R_f(EtOAc–light petroleum, 2 : 8) 0.7; ν_{max}(film)/cm^{-1} 1710 (CO), 1649 (C=C), 1603 (C=C), 1453, 1252 (SiMe), 1192, 845 and 759; δ_H(250 MHz, $CDCl_3$) 4.75 (1 H, m, CH=C), 4.50 (1 H, m, C$H_A$$CH_B$=C), 4.30 (1 H, m, CH_ACH_B=C), 3.65 (1 H, t, *J* 5.8, CHO), 2.05–1.80 (5 H, m, *Me*C=CH_2, two C*H*Me_2), 0.95 (12 H, d, *J* 6.6, two *Me*$_2$CH) and 0.27 (9 H, s, $SiMe_3$); *m*/*z* (EI) 270 (70%, M^+) 157 (63%) and 73 (87%, OTMS)(Found: M^+, 270.2014. $C_{15}H_{30}O_2Si$ requires *M*, 270.2015).

2′,4′-Dimethylpent-3′-yl (7*R*,11*R*)-3,7,11,15-tetramethyl-5-hydroxyhexadec-2-enoate 24

The silyl enol ether **23** (prepared from 0.1 g of the ester, 0.5 mmol) in dichloromethane (0.5 cm^3) was added to a mixture of the aldehyde **22** (35 mg, 0.16 mmol) in dichloromethane

(1.0 cm^3) and titanium tetrachloride (1.0 mol dm^{-3} solution in dichloromethane, 0.5 cm^3, 0.5 mmol) at −78 °C over 5 min. The mixture was stirred at −78 °C for 1 h, and then warmed to room temperature, quenched with saturated sodium hydrogencarbonate solution (5 cm^3), and extracted with ether (3 × 4 cm^3). The combined organic layers were washed with brine (5 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2; EtOAc–light petroleum, 2 : 98 to 5 : 95) to give the *alcohol* **24** (45 mg, 67%); R_f(EtOAc–light petroleum, 2 : 8) 0.5; ν_{max}(film)/cm^{-1} 3384 (OH), 1712 (CO), 1620 (C=C), 1514, 1219 and 1130; δ_H(400 MHz, $CDCl_3$) 5.88 (1 H, s, CH=C), 4.60 (1 H, t, *J* 6.2, CHOCO), 3.95–3.78 (1 H, m, C*H*OH), 3.10–2.97 (1 H, m, CH_ACH_BC=CH), 2.38–2.29 (1 H, m, $CH_AC\mathit{H}_BC$=CH), 1.97 (3 H, s, *Me*C=CH), 1.95–1.84 (2 H, m, two C*H*Me_2), 1.77–1.01 [17 H, series of m's, $CH_2CH(CH_2)_3CH(CH_2)_3CH$] and 0.95–0.81 (24 H, superimposed ds, *Me*CH, *Me*CH and three Me_2CH); δ_C(62.5 MHz, $CDCl_3$) 168.2+, 157.0+, 118.7−, 82.4−, 68.9−, 46.7+, 42.2+, 41.7+, 39.4+, 38.2+, 37.3+, 32.8−, 29.7−, 29.4−, 28.0−, 25.9−, 24.8+, 24.3+, 22.7−, 20.2−, 19.5− and 17.2−; *m*/*z* (ESI) 447 (80%, $M^+ + Na^+$), 279 (98%) and 249 (100%)(Found: M^+ + Na, 447.3827. $C_{27}H_{52}O_3$ requires *M* + Na, 447.3814).

2′,4′-Dimethylpent-3′-yl (7*R*,11*R*)-3,7,11,15-tetramethyl-5-methanesulfonyloxyhexadec-2-enoate

The alcohol **24** (30 mg, 0.07 mmol), methanesulfonyl chloride (16 μl, 0.21 mmol) and triethylamine (48 μl, 0.35 mmol) were stirred in dichloromethane (0.3 cm^3) at 0 °C for 1 h. The mixture was quenched with water (5 cm^3) and extracted with ether (3 × 4 cm^3). The combined extracts were washed with brine (5 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2; EtOAc–light petroleum, 2 : 98 to 4 : 95) to give the *mesylate* (26 mg, 74%); R_f(EtOAc–light petroleum, 2 : 8) 0.52; ν_{max}(film)/cm^{-1} 1709 (CO), 1629, 1366 (SO_2), 1314, 1171, 1054, 967, 796 and 750; δ_H(400 MHz, $CDCl_3$) 5.76 (1 H, s, CH=C), 5.05–5.92 (1 H, m, C*H*OMs), 4.61 (1 H, t, *J* 6.2, CHOCO), 2.95 (3 H, s, SO_2Me), 2.65–2.40 (2 H, m, CH_2C=CH), 2.21 (3 H, s, *Me*C=CH), 1.95–1.84 (2 H, m, two C*H*Me_2), 1.65–1.55 (2 H, m, CH_2CHOMs), 1.55–1.00 [15 H, series of m's, $CH(CH_2)_3CH(CH_2)_3CH$] and 0.95–0.80 (24 H, superimposed ds, *Me*CH, *Me*CH and three Me_2CH); δ_C(100 MHz, $CDCl_3$) 166.0 +, 152.8+, 119.9−, 81.9−, 79.6−, 79.2−, 46.6+, 45.9+, 41.9+, 39.1+, 38.5−, 37.3+, 37.1+, 32.5−, 29.1−, 28.8−, 27.7−, 25.1+, 24.5+, 22.4−, 22.3−, 19.4−, 18.7− and 17.0−; *m*/*z* (ESI) 525 (100%, $M^+ + Na^+$)(Found: M^+ + Na, 525.3590. $C_{28}H_{34}O_3S$ requires *M* + Na, 525.3590).

(7*R*,11*R*,2*E*)-3,7,11,15-Tetramethylhexadec-2-en-1-ol (phytol) 25

Lithium aluminium hydride (~20 mg) and the mesylate (26 mg, 0.05 mmol) were refluxed in ether (2 cm^3) overnight. The mixture was cooled to room temperature, poured into water (10 cm^3), and extracted with ether (3 × 4 cm^3). The combined organic layers were washed with brine (5 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2; EtOAc–light petroleum, 5 : 95) to give phytol (10 mg, 67%); R_f(EtOAc–light petroleum, 2 : 8) 0.36; ν_{max}(film)/cm^{-1} 3263 (OH), 1839, 1725 (C=C), 1458 and 995; δ_H(400 MHz, $CDCl_3$) 5.41 (1 H, tq, *J* 7.0 and 1.3, CH=C), 4.16 (2 H, br s, CH_2OH), 2.00 (2 H, t, *J* 7.5, CH_2C=CH), 1.67 (3 H, s, *Me*C=CH), 1.57–0.99 [19 H, series of ms, $(CH_2)_2CH(CH_2)_3$-$CH(CH_2)_3CH$] and 0.95–0.80 (12 H, superimposed ds, *Me*CH, *Me*CH, Me_2CH); δ_C(100 MHz, $CDCl_3$) 123.1−, 59.4+, 39.9+, 39.4+, 37.4+, 36.8+, 32.8−, 32.7−, 28.0−, 25.2+, 24.8+, 24.5+, 22.7−, 22.6−, 19.7−, 19.6− and 16.2−, matching values in the literature (140.19s, 123.11d, 59.40t, 39.88t, 39.39t, 37.44q, 37.38t, 37.31t, 36.37t, 32.81d, 32.71d, 27.99d, 25.17t, 24.81t, 24.49t, 22.72q, 22.63q, 19.75q, 16.18q)[39] except that we saw an unresolved single line at δ 37.4, and did not see the presumably weak line at δ 140.19; *m*/*z* (ESI) 319 (67%, $M^+ + Na^+$) 256 (100%)(Found: M^+ + Na, 319.2964. $C_{20}H_{40}O$ requires *M* + Na, 319.2977).

(3*R*,5*S*)-3-Dimethyl(phenyl)silyl-5-methylcyclohexanone 6

This compound was obtained as a by-product in several reactions using the silylzincate and silylcuprate conjugate additions; R_f(EtOAc–light petroleum, 2 : 8); 0.60 ν_{max}($CDCl_3$)/cm^{-1} 1703 (C=O), 1427, 1320, 1251 (SiMe), 1176, 1116 (SiPh), 1020 and 833; δ_H(400 MHz, $CDCl_3$) 7.48–7.33 (5 H, m, Ph), 2.47–2.36 (2 H, m, CH_AH_BCO and CHSiCH_AH_BCO), 2.27–2.21 (1 H, m, CHSiCH_AH_BCO), 2.12–2.05 (2 H, m, MeC*H*CH_AH_BCO), 1.77–1.69 (1 H, m, CHSi), 1.60–1.50 (CH_2CHSi), 0.95 (3 H, d, *J* 6.9, Me), 0.30 (3 H, s, SiMe_AMe_B) and 0.29 (3 H, s, SiMe_A-Me_B); δ_C(100 MHz, $CDCl_3$) 212.9+, 136.6+, 133.9−, 129.2−, 127.8−, 52.5−, 48.2+, 42.0+, 32.6−, 31.9+, 21.1−, 19.1−, −5.1− and −5.2−; *m*/*z* (EI) 246 (M^+), 135 ($PhMe_2Si^+$)(Found: M^+, 246.1432. $C_{15}H_{22}OSi$ requires *M*, 246.1440).

(5*R*)-5-Methylcyclohex-2-enone 1

The ketone **6** (150 mg, 0.61 mmol) in chloroform (2 cm^3) was refluxed with a suspension of copper(II) bromide (273 mg, 1.22 mmol) in ethyl acetate (2 cm^3) for 1 h. The mixture was cooled to room temperature, and diluted with carbon tetrachloride (5 cm^3). The precipitate was filtered off through a sintered funnel, washing with carbon tetrachloride (2 × 3 cm^3). The filtrate was evaporated under reduced pressure and the residue chromatographed (SiO_2, EtOAc–light petroleum 5 : 95 to 10 : 90) to give the cyclohexenone **1** (35 mg, 55%), identical (TLC, ^{1}H-NMR) with the sample used earlier.

(5*R*)-2-(Pyran-2′-yl)-5-methylcyclohex-2-enone 26

Diethylaluminium iodide (1.0 mol dm^{-3} solution in hexane, 2.8 cm^3, 2.8 mmol) was added to 5-methylcyclohexenone **1** (200 mg, 1.8 mmol) and 5-*tert*-butyldimethylsilyloxyhexanal[40] (600 mg, 2.8 mmol) in dichloromethane (2 cm^3) at 0 °C and stirred for 1 h. The mixture was warmed to room temperature, diluted with ether (10 cm^3), poured into water (10 cm^3) and extracted with ether (3 × 5 cm^3). The combined organic layers were washed with brine (10 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 5 : 95) to give the *ketone* **26** (262 mg, 74%); R_f(EtOAc–light petroleum, 2 : 8) 0.36; ν_{max}-(film)/cm^{-1} 3184, 1709 (CO), 1665 (CO), 1568, 1237, 1094 and 901; δ_H(500 MHz, $CDCl_3$) 6.96 (1 H, t, *J* 2.8, CH=C), 4.21 (1 H, dd, *J* 17.7 and 10.9, CH=CC*H*O), 4.03–395 (1 H, m, CH_AH_BO), 3.50 (1 H, td, *J* 11.4 and 2.6, CH_AH_BO), 2.47–2.37 (2 H, m, CH_AH_BCHMeCH_AH_BCO), 2.20–2.16 (3 H, m, CH_AH_B-C*H*MeCH_AH_BCO), 1.85–1.76 (2 H, m, CH_AH_BCH_AH_BCHO), 1.65–1.45 (3 H, m, C$H_2CH_AH_BCH_AH_B$CHO), 1.15–1.06 (1 H, m, CH_AH_BCHO) and 1.02 (3 H, d, *J* 6.2, *Me*CH); δ_C(125 MHz, $CDCl_3$) 198.3+, 144.1−, 141.1+, 73.7−, 69.0+, 46.6+, 34.0+, 32.7+, 30.2−, 26.0+, 23.6+ and 21.2−; *m*/*z* (EI) 194 (46%, M^+)(Found: M^+, 194.1299. $C_{12}H_{18}O_2$ requires *M*, 194.1307).

(3*R*,5*S*)-3-[Dimethyl(phenyl)silyl]-5-methyl-2-(tetrahydropyran-2′-yl)cyclohexanone 27 and (3*R*,5*S*)-3-[dimethyl(phenyl)silyl]-2-(5′-hydroxypentylidene)-5-methylcyclohexanone 28

Dimethyl(phenyl)silyllithium (0.96 mol dm^{-3} in THF, 0.8 cm^3, 0.77 mmol) was added dropwise to a stirred solution of dimethylzinc (2 mol dm^{-3} in toluene, 0.8 cm^3, 1.5 mmol) in THF (0.5 cm^3) at −78 °C and stirred for 30 min. The enone **26** (100 mg, 0.5 mmol) in THF (1 cm^3) was added at −78 °C and the mixture stirred for 1 h. The mixture was warmed to room temperature and quenched with saturated aqueous ammonium chloride solution (5 cm^3). The mixture was extracted with ether (3 × 7 cm^3). The extracts were washed with water (10 cm^3), brine

(10 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 5 : 95 to 40 : 60) to give the *ketone* **27** (28 mg, 17%); R_f(EtOAc–light petroleum, 1 : 1) 0.5; ν_{max}(film)/cm^{-1} 1704 (C=O), 1452, 1430, 1256 (SiMe), 1087 (SiPh), 1043 and 766; δ_H(500 MHz, $CDCl_3$) 7.51–7.32 (5 H, m, Ph), 3.93 (1 H, ddd, *J* 11.4, 2.1 and 1.9, CH_ACH$_B$O), 3.54 (1 H, ddd, *J* 8.4, 3.8 and 4.6, CHO), 3.35 (1 H, td, *J* 11.4 and 2.6, CH$_A$$H_B$O), 2.40 (1 H, d, *J* 8.0, CHCO), 2.25 (1 H, d, *J* 13.0, CH_AH$_B$CO), 2.01–1.20 (11 H, series of ms, CH$_A$$H_B$CO, C*H*Me, CH_2CHSi and CH_2-CH_2CH_2CH$_2$O), 0.92 (3 H, d, *J* 6.1, CH*Me*) and 0.26 (6 H, s, $SiMe_2$); δ_C(125 MHz, $CDCl_3$) 213.3+, 137.9+, 133.7−, 128.9−, 127.6−, 74.4−. 68.6+, 56.0− 49.2+, 32.7−, 30.9+, 29.6+, 25.8+, 23.3−, 23.2+, 22.7−, −3.0− and −3.0−; *m*/*z* (EI) 330 (20%, M^+), 135 (55%, $SiMe_2$Ph), 69 (100%, $CH_2CH_2CH_2CH_2$-CH)(Found: M^+ + Na, 330.2026. $C_{20}H_{30}O_2Si$ requires *M* + Na, 330.2015), and the *alcohol* **28** (71 mg, 42%); R_f(EtOAc–light petroleum, 1 : 1) 0.3; ν_{max}(film)/cm^{-1} 3431 (OH), 1731 (CO), 1676 (C=C), 1608, 1256 (SiMe), 1142 (SiPh), 1065 and 1016; δ_H(500 MHz, $CDCl_3$) 7.46–7.28 (5 H, m, Ph), 6.17 (1 H, dd, *J* 8.5 and 6.0, CH=C), 3.54 (2 H, t, *J* 6.5, CH_2OH), 2.62 (1 H, d, *J* 4.6, CHSi), 2.44 (1 H, dd, *J* 16.1 and 4.2, CH_AH$_B$CO), 2.01–1.75 (4 H, m, CH$_A$$H_BCO, CH_AH_B$CHSi and C$H_2$CH=C), 1.58–1.47 (2 H, m, C*H*Me, CH$_A$$H_B$CHSi), 1.47–1.34 (2 H. m, CH_2CH$_2$OH), 1.33–1.24 (2 H, m, CH_2CH$_2$CH$_2$OH), 0.90 (3 H, d, *J* 6.2, Me), 0.30 (3 H, s, Si*Me*$_A$Me$_B$) and 0.26 (3 H, s, $SiMe_A$-*Me*$_B$); δ_C(125 MHz, $CDCl_3$) 202.9+, 138.9+, 137.6+, 134.1−, 133.9−, 129.3−, 127.8−, 62.6+, 48.9+, 34.6+, 32.3+, 29.5−, 27.9−, 27.6+, 24.9+, 22.5−, −2.9− and −3.1−; *m*/*z* (ESI) 353 (100%, M^+ + Na^+) (Found: M^+ + Na, 353.1916. $C_{20}H_{30}O_2Si$ requires *M* + Na, 353.1913).

(3*R*,5*S*)-3-Dimethyl(phenyl)silyl-5-methyl-2-(5′-oxopentylidene)cyclohexanone 29

A solution of dry dimethyl sulfoxide (0.04 cm^3, 0.59 mmol) in dry dichloromethane (0.2 cm^3) was added dropwise to a stirred solution of oxalyl chloride (2 mol dm^{-3} solution in dichloromethane, 0.15 cm^3, 0.29 mmol) at −78 °C. After 20 min a solution of the alcohol **28** (65 mg, 0.19 mmol) in dry dichloromethane (0.2 cm^3) was added dropwise and the mixture stirred for 10 min. Dry, freshly distilled triethylamine (0.14 cm^3, 0.98 mmol) was added and the mixture was warmed to 0 °C, quenched with water (5 cm^3), and extracted with ether (3 × 5 cm^3). The combined organic layers were washed with brine (5 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 3 : 97) to give the *aldehyde* (53 mg, 89%); R_f(EtOAc–light petroleum 3 : 7) 0.4; ν_{max}(solution cell, $CDCl_3$)/cm^{-1} 1793 (CO), 1709 (CO), 1600 (C=C), 1466, 1255 (SiMe), 1118 (SiPh) and 903; δ_H(500 MHz, $CDCl_3$) 9.66 (1 H, s, CHO), 7.46–7.30 (5 H, m, Ph), 6.13 (1 H, dd, *J* 6.3 and 6.0 CH=C), 2.59 (1 H, d, *J* 4.8, CHSi), 2.46 (1 H, d, *J* 16.0, CH_AH$_B$CO), 2.25 (2 H, t, *J* 6.6, CH_2CHO), 2.05–1.85 (3 H, m, CH$_A$$H_BCO, CH_AH_B$C*H*Si and C*H*Me), 1.85–1.75 (1 H, m, CH_AH$_B$CH=C), 1.57–1.44 (2 H, m, CH$_A$$H_B$CH=C and CH$_A$$H_B$C*H*Si), 0.93 (3 H, d, *J* 6.2, CH*Me*), 0.88–0.82 (2 H, m, CH_2CH$_2$CHO), 0.32 (3 H, s, Si*Me*$_A$-Me$_B$) and 0.28 (3 H, s, $SiMe_A$*Me*$_B$); δ_C(125 MHz, $CDCl_3$) 202.7+, 202.1−, 139.7+, 137.5+, 133.9−, 132.6−, 129.3−, 127.8−, 48.9+, 43.1+, 34.6+, 29.5−, 28.1−, 27.0+, 22.5−, 21.3+, −3.0− and −3.2−; *m*/*z* (ESI) 351 (100%, M^+ + Na^+)(Found: M^+ + Na, 351.1746. $C_{20}H_{28}O_2Si$ requires *M* + Na, 351.1756).

(3*R*,5*S*,1′*R*,2′*R*)-3-Dimethyl(phenyl)silyl-2-(2′-hydroxycyclopentyl)-5-methylcyclohexanone 30

Modifying the recipes of Molander, Hon and Fukuzawa,[41] samarium (104 mg, 0.69 mmol, weighed in glove box) and diiodomethane (38 µl, 0.47 mmol) were stirred in THF (5 cm^3) at room temperature under argon for 4 h. HMPA (80 µl, 0.46 mmol) was added whereupon the solution changed from intense blue to yellow. The aldehyde **29** (45 mg, 0.14 mmol) in THF (2 cm^3) and *tert*-butanol (40 µl, 0.42 mmol) was added dropwise to the yellow solution and the mixture stirred at room temperature for 15 min. The mixture was quenched with sodium hydrogencarbonate (10 cm^3) and extracted with ether (3 × 5 cm^3). The combined organic extracts were washed with brine (10 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The reside was chromatographed (SiO_2, EtOAc–light petroleum, 5 : 95) to give the *alcohol* **30** (20 mg, 43%); R_f-(EtOAc–light petroleum, 3 : 7) 0.35; ν_{max}(film)/cm^{-1} 3219 (OH), 1692 (CO), 1650, 1112 (SiPh), 978 and 859; δ_H(500 MHz, $CDCl_3$) 7.55–7.30 (5 H, m, Ph), 3.69–3.64 (1 H, m, C*H*OH), 2.25–2.03 (3 H, m, CH_2CO and CHCO), 1.91–0.78 (11 H, series of ms, $CHCH_2$CHSi and C*H*CH_2CH_2CH_2CHO), 0.95 (3 H, d, *J* 6.3, *Me*CH) and 0.29 (6 H, s, $SiMe_2$); δ_C(125 MHz, $CDCl_3$) 213.7+, 137.8+, 133.7−, 129.1−, 127.8−, 78.6−, 53.8−, 48.7−, 47.7+, 35.7+, 33.1−, 30.6+, 29.7+, 28.6+, 26.8+, 22.8+, 22.6− and −3.3−; *m*/*z* (ESI) 353 (100%, M^+ + Na^+)(Found: M^+ + Na, 353.1897. $C_{20}H_{30}O_2Si$ requires *M* + Na, 353.1913).

(3*R*,5*S*,1′*R*,2′*R*)-3-Dimethyl(phenyl)silyl-2-[2′-(3,5-dinitrobenzoyloxy)cyclopentyl]-5-methylcyclohexanone

The alcohol **30** (20 mg, 0.06 mmol), 3,5-dinitrobenzoyl chloride (70 mg, 0.30 mmol) and DMAP (8 mg, 0.06 mmol) were stirred in dichloromethane (1 cm^3) and pyridine (0.5 cm^3) at room temperature for 30 min, during which time a white solid precipitated. The mixture was quenched with water (5 cm^3) and extracted with ether (3 × 5 cm^3). The combined organic layers were washed with brine (5 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The reside was chromatographed (SiO_2, EtOAc–light petroleum, 5 : 95) to give the *ester* (28 mg, 89%) as needles; mp 142 °C (from hexane); R_f(EtOAc–light petroleum, 3 : 7) 0.2; ν_{max}(film)/cm^{-1} 1732 (CO), 1638, 1548 (NO_2), 1381 (NO_2), 1295 (SiMe), 1216, 1167, 1095 (SiPh), 895 and 732; δ_H(500 MHz, $CDCl_3$) 9.23 (1 H, t, *J* 2.2, *p*-C_6H_3-$(NO_2)_2$], 9.18 [2 H, d, *J* 2.2, *o*-$C_6H_3(NO_2)_2$], 7.58–7.38 (5 H, m, Ph), 5.09 (1 H, dt, *J* 6.5 and 3.2, CHO), 2.50 (1 H, dd, J 11.7 and 5.9, SiCHC*H*), 2.45 (1 H, td, J 7.5 and 3.2, CH_AH$_B$CHO), 2.39–2.32 (1 H, m, CH_AH$_B$CO), 2.05–0.81 (11 H, series of ms, CH$_A$$H_B$C*H*(Me)C$H_2$C*H*(Si)CHC*H* C$H_2CH_2CH_A$$H_B$), 0.95 (3 H, d, *J* 6.2, *Me*CH), 0.37 (3 H, s, Si*Me*$_A$Me$_B$) and 0.30 (3 H, s, $SiMe_A$*Me*$_B$); δ_C(125 MHz, $CDCl_3$) 211.5+, 162.1+, 148.6+, 140.8+, 134.9+, 133.6−, 129.5−, 129.2−, 127.9−, 121.9−, 83.2−, 57.8−, 50.3+, 44.7−, 34.1−, 33.4+, 29.9+, 29.3−, 23.4+, 22.6−, −1.1− and −1.9−; *m*/*z* 547 (100%, M^+ + Na^+) (Found: M^+ + Na, 547.1880. $C_{27}H_{32}N_2O_7Si$ requires *M* + Na, 547.1979).

Crystal data. $C_{27}H_{32}N_2O_7$ Si, *M* = 524.64, orthorhombic, space group $P2_12_12_1$ (no. 19), *a* = 7.1067(1), *b* = 14.8638(4), *c* = 26.2267(7) Å, *U* = 2770.4(1) Å^3, *Z* = 4, μ(Mo–Kα) = 0.131 mm^{-1}, 17591 reflections measured at 180(2) K using an Oxford Cryosystems Cryostream cooling apparatus, 6153 unique (R_{int} = 0.046); R_1 = 0.041, wR_2 = 0.083 [$I>2\sigma(I)$]. The structure was solved with *SHELXS-97* and refined with *SHELXL-97*.[31] CCDC reference numbers 212800–212802. See http://www.rsc.org/suppdata/ob/b3/b305880h/ for crystallographic data in .cif or other electronic format.

(3*R*,5*S*)-3-Dimethyl(phenyl)silyl-5-methyl-1-trimethylsilyloxycyclohex-1-ene 32

Dimethyl(phenyl)silyllithium (1.0 mol dm^{-3} solution in THF, 1.1 cm^3, 1.1 mmol) was added dropwise to a stirred solution of diethylzinc (1.0 mol dm^{-3} in toluene, 1.1 cm^3, 1.1 mmol) in THF (0.5 cm^3) at −78 °C and stirred for 30 min. 5-Methylcyclohex-2-enone **1** (100 mg, 0.9 mmol) in THF (1 cm^3) was added at

−78 °C and the mixture stirred for 1 h. Chlorotrimethylsilane (0.23 cm^3, 1.8 mmol) was added and the mixture warmed to 0 °C over a period of 30 min, and then to room temperature. The mixture was quenched with saturated aqueous ammonium chloride solution, and extracted with ether (3 × 5 cm^3). The combined organic layers were washed with water (10 cm^3), brine (10 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, light petroleum) to give the *silyl enol ether* **32** (269 mg, 94%); R_f(EtOAc–light petroleum, 1 : 9) 0.64; $\nu_{max}(CDCl_3)/cm^{-1}$ 1718, 1657 (C=C), 1427, 1253 (SiMe), 1181, 1118 (SiPh), 1047 and 838; δ_H(500 MHz, $CDCl_3$) 7.54–7.30 (5 H, m, Ph), 4.84 (1 H, d, *J* 3.6, CH=C), 2.05 (1 H, dd, *J* 16.7 and 5.7, CH_AH_BCO), 1.86–1.76 (2 H, m, CHSi and C*H*Me), 1.65 (1 H, dd, J 16.7 and 5.3 CH_AH_BCO), 1.58–1.48 (1 H, m, CH_AH_BCHSi), 1.38–1.31 (1 H, m, CH_AH_B-CHSi), 0.90 (3 H, d, *J* 6.6, Me), 0.28 (3 H, s, Si$Me_A$$Me_B$), 0.27 (3 H, s, $SiMe_AMe_B$) and 0.15 (9 H, s, $SiMe_3$); δ_C(125 MHz, $CDCl_3$) 148.0+, 138.4+, 133.9−, 128.8−, 127.7−, 104.4−, 37.3+, 30.2+, 27.1−, 21.4−, 20.2−, 0.4−, −4.3− and −4.4−; *m*/*z* (EI) 318 (20%, M^+), 245 (51%, M^+ − TMS), 183 (98%, M^+ − $SiMe_2Ph$), 135 (92%, $SiMe_2Ph$) and 73 (100%, TMS) (Found: M^+, 318.1921. $C_{18}H_{30}OSi_2$ requires *M*, 318.1835).

6-Hydroxyhexan-2-one

Hex-5-en-2-one (1.0 g, 10.2 mmol) and 9-BBN (20 cm^3, 10.2 mmol) were stirred under argon at room temperature for 4 h. Sodium perborate (3.1 g, 30.6 mmol) was added to the mixture and stirred at room temperature for 1 h. Water (10 cm^3) was added and stirring was continued for an additional 2 h at 50 °C and 10 h at room temperature. The mixture was extracted with ether (3 × 15 cm^3) and the solvent was removed under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 40 : 60) to give the alcohol[42] (1.2 g, 72%); R_f(EtOAc–light petroleum, 7 : 3) 0.20; ν_{max}(film)/cm^{-1} 3434 (br, OH) and 1680 (CO); δ_H(250 MHz, $CDCl_3$) 3.62 (2 H, t, *J* 7.3, CH_2OH), 2.47 (2 H, t, *J* 7.0, CH_2COMe), 2.15 (3 H, s, Me), 1.80 (1 H, br s, OH) and 1.71–1.45 (4 H, m, CH_2CH_2CH_2OH); δ_C(100 MHz, $CDCl_3$) 207.1, 61.4, 41.5, 30.0, 22.6 and 17.7.

1,5-Hexanedione

Method A. The ketoalcohol (0.15 g, 1.31 mmol), pyridinium chlorochromate (0.35 g, 1.63 mmol) and molecular sieves (4 Å) (0.1 g) were stirred in dichloromethane (10 cm^3) at 0 °C for 5 min. The mixture was warmed to room temperature and stirred for a further 4 h. Ether (10 cm^3) was added to the mixture and the mixture stirred for a further 30 min. The solid precipitate was filtered off through a silica pad, washing with ether. The solvent was evaporated off under reduced pressure and the residue was chromatographed [SiO_2, EtOAc–light petroleum (bp 30–40 °C), 1:99] to give the ketoaldehyde[43] (0.12 g, 83%); R_f(EtOAc–light petroleum 3 : 7) 0.22; δ_H(400 MHz, $CDCl_3$) 9.73 (1 H, t, *J* 1.3, CHO), 2.51–2.42 (4 H, m, CHOCH_2-CH_2CH_2CO), 2.11 (3 H, s, MeCO) and 1.85 (2 H, q, *J* 3.6, CH_2C$H_2$$CH_2$); δ_C(100 MHz, $CDCl_3$) 208.0+, 201.8−, 42.2+, 32.7+, 29.8+ and 18.5+.

Method B. Oxygen was bubbled through a solution of 1-methylcyclopentene (1.5 g, 18.3 mmol) in dichloromethane (150 cm^3) and methanol (150 cm^3) for 2 min at −78 °C, and then ozone was passed through at the same temperature until the blue colour appeared. Dimethyl sulfide (15 cm^3) was added, the mixture was warmed to room temperature, and stirred overnight. Evaporation of the solvent gave the ozonide[44] (1.036 g, 45%); R_f(EtOAc–light petroleum, 3 : 7) 0.18; ν_{max}(film)/cm^{-1} 1718.1, 1447 (CO), 1382, 971 and 628; δ_H(400 MHz, $CDCl_3$) 5.77 (1 H, br s, CHO), 2.30–2.15 (1 H, m, CH_AH_B), 1.85–1.72 (4 H, m, CH_2CH_2), 1.70–1.60 (1 H, m, CH_AH_B) and 1.55 (3 H, s, Me); δ_C(100 MHz, $CDCl_3$) 107.8+, 102.9−, 34.2+, 28.9+, 22.3+ and 21.0−; *m*/*z* (EI) 130 (17%, M^+) (Found: M^+, 130.0627. $C_6H_{10}O_3$ requires *M*, 130.0630). The ozonide (1.036 g, 7.92 mmol) and dimethyl sulfide (15 cm^3) were refluxed in dichloromethane (30 cm^3) for 10 h. The mixture was cooled to room temperature, poured into water (25 cm^3), and extracted with ether (3 × 10 cm^3). The combined extracts were washed with brine (10 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure to give the ketoaldehyde (0.99 g, 94%) identical (^{1}H-NMR) with the sample obtained earlier.

(3*R*,5*S*)-3-(Dimethylphenylsilyl)-5-methyl-2-(5′-oxohexylidene)-cyclohexanone 33

The silyl enol ether **32** (100 mg, 0.314 mmol) in dichloromethane (1 cm^3) was added dropwise to a stirred mixture of titanium tetrachloride (1 mol dm^{-3} in dichloromethane, 0.69 cm^3, 0.69 mmol) and the ketoaldehyde (35 mg, 0.314 mmol) in dichloromethane (0.1 cm^3) at −78 °C. The mixture was warmed to 0 °C over a period of 1 h and then to room temperature. The mixture was quenched with a saturated solution of sodium hydrogencarbonate (5 cm^3) and neutralised with hydrochloric acid (3 mol dm^{-3}, 5 cm^3). The aqueous solution was extracted with ether (3 × 5 cm^3), washed with brine (5 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 93 : 7 to 80 : 20) to give the *enone* **33** (25 mg, 24%); R_f(EtOAc–light petroleum, 3 : 7) 0.22; $\nu_{max}(CDCl_3)/cm^{-1}$ 1710 (CO), 1677 (CO), 1646 (C=C), 1604, 1165 (SiPh), 1095, 895 and 699; δ_H(400 MHz, $CDCl_3$) 7.48–7.30 (5 H, m, Ph), 6.19–6.12 (1 H, m, CH=C), 2.61 (1 H, d, *J* 5.0, MeCHCH_AH_BCO), 2.42–2.40 (1 H, m, CHSi), 2.28 (2 H, t, *J* 7.2, CH_2COMe), 2.09 (3 H, s, MeCO), 2.04–1.75 (4 H, m, MeC*H*CH_AH_BCO and C=CHCH_2), 1.60–1.42 (4 H, m, C$H_2$$CH_2$COMe and C$H_2$CHSi), 0.92 (3 H, d, *J* 6.2, *Me*CH), 0.31 (3 H, s, Si$Me_A$$Me_B$) and 0.28 (3 H, s, $SiMe_AMe_B$); δ_C(100 MHz, $CDCl_3$) 208.4+, 202.6+, 139.5+, 137.6+, 133.9−, 133.1−, 129.3−, 127.9−, 48.9+, 42.9+, 34.7+, 29.5−, 28.1−, 27.1+, 22.9+, 22.4−, −3.1− and −3.1−; *m*/*z* (ESI) 365 (100%, M^+ + Na^+)(Found: M^+ + Na, 365.1926. $C_{21}H_{30}O_2Si$ requires *M* + Na, 365.1913). This compound was also made using a route analogous to the preparation of the enone **2** by way of the aldol **7**, but the overall yield was no better.

(3*R*,5*S*)-2-(3′-Oxocyclohexyl)-3-dimethyl(phenyl)silyl-5-methylcyclohexanone 35

Potassium *tert*-butoxide (33 mg, 0.29 mmol) and the ketone **33** (100 mg, 0.29 mmol) in *tert*-butanol (2 cm^3) were stirred at room temperature for 1 h, following the disappearance of the starting material by TLC. The solvent was removed and the residue was chromatographed (SiO_2, EtOAc–light petroleum, 20 : 80) to give the mixture of *diketones* **35** (21 mg, 22%); R_f-(EtOAc–light petroleum, 2 : 8) 0.18; ν_{max}(solution cell, $CDCl_3$)/cm^{-1} 1793 (CO), 1703 (CO), 1647 (Ph), 1602, 1253 (SiMe), 1232, 1111 (SiPh), 898 and 661; δ_H(400 MHz, $CDCl_3$) 7.52–7.34 (5 H, m, Ph), 2.30–1.10 (16 H, series of ms, MeC*H*CH_2CO, CH_2CH(Si)CHCHCH_2CO and $CH_2$$CH_2$$CH_2$CO), 0.95–0.91 (3 H, 2 × d, *J* 5.9 and 5.0, *Me*CH two isomers) and 0.30–0.27 (6 H, 3 ss, $SiMe_2Ph$ two isomers); δ_C(100 MHz, $CDCl_3$) 213.7+, 212.7+, 137.1+, 133.4−, 129.0−, 127.6−, 55.8−, 48.0+, 38.8−, 32.5−, 30.5+, 30.4+, 29.3+, 28.5+, 25.6−, 22.2+, 22.1−, −3.4− and −3.6−; *m*/*z* (EI) 342 (25%, M^+), 135 (100%, $SiMe_2Ph$)(Found: M^+ 342.2030, $C_{21}H_{30}O_2Si$ requires *M*, 342.2015), and the ketone **6** (31 mg, 43%), identical (TLC, ^{1}H-NMR) to the earlier sample.

(3*R*,5S)-3-Dimethyl(phenyl)silyl-2-(3′-hydroxyclohexyl)-5-methylcyclohexanone

The diketone **35** (45 mg, 0.131 mmol) and sodium borohydride (100 mg, 2.64 mmol) were stirred in methanol (2 cm^3) at 0 °C for 30 min. The mixture was warmed to room temperature, quenched with water (5 cm^3), and extracted with ether (3 ×

4 cm^3). The combined extract was washed with brine (5 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 20 : 80 to 70 : 30) to give three *diol*s **A** (5 mg, 12%), **B** (18 mg, 40%) and **C** (19 mg, 42%); **A**: R_f(EtOAc–light petroleum, 7 : 3) 0.64; $\nu_{max}(CDCl_3)/cm^{-1}$ 3649 (OH), 1739, 1255 (SiMe), 1183, 1108 (SiPh), 1043 and 882; δ_H(500 MHz, $CDCl_3$) 7.63–7.57 (2 H, m, *m*-Ph), 7.34–7.30 (3H, m, *o,p*-Ph), 4.09 (1 H, br s, SiCHCHC*H*OH), 3.04 (1 H, tt, *J* 10.6 and 4.2, CHCHCH$_2$-C*H*OH), 1.99–0.54 (16 H, series of m's, MeC*H*CH_2, CH$_2$CH-(Si)CHCHCH$_2$ and CH_2CH_2CH_2CHO), 0.79 (3 H, d, *J* 6.4, *Me*CH), 0.43 (3 H, s, SiMe_AMe$_B$) and 0.39 (3 H, s, SiMe$_A$$Me_B$); δ_C(125 MHz, $CDCl_3$) 141.6+, 134.0−, 128.5−, 127.6−, 70.3−, 66.4−, 51.2−, 42.9+, 41.3+, 37.5+, 35.8−, 35.3+, 29.6+, 24.1−, 23.8+, 23.6−, 22.3−, −0.0− and −0.5−; *m*/*z* (ESI) 369 (100%, $M^+ + Na^+$) (Found: $M^+ + Na^+$ 369.2233, $C_{21}H_{34}O_2Si$ requires *M* + *Na*, 346.2328); **B**: R_f(EtOAc–light petroleum, 7 : 3) 0.40; $\nu_{max}(CDCl_3)/cm^{-1}$ 3608 (OH), 3461 (OH), 1793, 1640, 1601, 1251 (SiMe), 1166 (SiPh) and 1095; δ_H(500 MHz, $CDCl_3$) 7.52–7.30 (5 H, m, Ph), 3.83 (1 H, dt, *J* 11.1 and 4.3, SiCHCHC*H*OH), 3.54 (1 H, tt, *J* 10.7 and 4.2, CHCHCH$_2$C*H*OH), 2.05–0.92 (16 H, series of m's, CH_2C*H*(Me)CH_2C*H*(Si)C*H*CHCH_2CH_2CH_2-CHCH_2), 0.90 (3 H, d, *J* 6.2, *Me*CH), 0.33 (3 H, s, SiMe_AMe$_B$) and 0.31 (3 H, s, SiMe$_A$$Me_B$); δ_C(125 MHz, $CDCl_3$) 139.2+, 133.6−, 128.7−, 127.7−, 71.3−, 68.3−, 51.3−, 48.8−, 44.4+, 38.8+, 36.7+, 35.5+, 35.2−, 33.0+, 29.7−, 24.0+, 22.6−, −2.5− and −3.7−; **C**: R_f(EtOAc–light petroleum, 7 : 3) 0.22; $\nu_{max}(CDCl_3)/cm^{-1}$ 3689 (OH), 3608 (OH), 1793, 1250 (SiMe), 1216, 1166 (SiPh), 1095 and 922; δ_H(500 MHz, $CDCl_3$) 7.51–7.46 (2 H, m, *m*-Ph), 7.36–7.31 (3 H, m, *o,p*-Ph), 3.84 (1 H, dt, *J* 11.0 and 4.2, SiCHCHC*H*OH), 3.41 (1 H, tt, *J* 10.6 and 4.4, CHCH-CH$_2$C*H*OH), 2.00–1.85 (2 H, 2 m's, CHCHCH_AH$_B$CHO and CH$_2$CH_AH$_B$CHO), 1.79–0.93 (14 H, MeC*H*CH_2, CH_2C*H*-(Si)C*H*CHCH$_A$$H_B$ and CH_2CH_2CH$_A$$H_B$CHO), 0.89 (3 H, d, *J* 6.4, *Me*CH), 0.33 (3 H, s, SiMe_AMe$_B$) and 0.31 (3 H, s, SiMe$_A$-Me_B); δ_C(125 MHz, $CDCl_3$) 139.2+, 133.7−, 128.9−, 127.7−, 71.8−, 70.8−, 44.5−, 42.6+, 39.8+, 35.4−, 35.3+, 31.7+, 30.7+, 29.6−, 24.0+, 23.2−, 22.4−, −2.1− and −2.7−; *m*/*z* (ESI) 369 (100%, $M^+ + Na^+$)(Found: M^+ + Na, 369.2219. $C_{21}H_{34}O_2Si$ requires *M* + Na, 346.2328).

(1*S*,2*S*,3*R*,5*S*,1′*S*,3′*R*)-3-Dimethyl(phenyl)silyl-2-(3′-3,5-dinitrobenzoyloxyclohexyl)-5-methylcyclohexan-1-ol

The diol **A** (10 mg, 0.03 mmol), 3,5-dinitrobenzoyl chloride (33 mg, 0.14 mmol), pyridine (0.5 cm^3) and DMAP (5 mg, 0.03 mmol) were stirred in dichloromethane (1 cm^3) at room temperature for 1 h, during which time a white solid precipitated. The mixture was quenched with water (5 cm^3) and extracted with ether (3 × 5 cm^3). The combined organic layers were washed with brine (5 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 5 : 95) to give the *mono ester* (16 mg, 99%); R_f(EtOAc–light petroleum, 2 : 8) 0.3; ν_{max}(solution cell, $CDCl_3$)/cm^{-1} 3473 (OH), 1726 (CO), 1627, 1601, 1213 (SiMe), 1045 and 928; δ_H(400 MHz, $CDCl_3$) 9.22 (1 H, t, *J* 2.1, *p*-$(NO_2)_2C_6H_3$), 9.14 [2 H, d, *J* 2.2, 2 × *o*-$(NO_2)_2C_6H_3$], 7.60 (2 H, m, 2 × *m*-Ph), 7.30 (3 H, m, 2 × *o*- and 1 × *p*-Ph), 4.60 (1 H, tt, *J* 8.9 and 4.3, CHOCO), 4.11 (1 H, br s, CHO*H*), 2.29–0.81 (16 H, series of ms, C*H*CH-(Si)CH_2C*H*(Me)CH_2 and CH$_2$CHCH$_2$CH$_2$CH$_2$), 0.80 (3 H, d, *J* 6.5, *Me*CH), 0.47 (3 H, s, SiMe_AMe$_B$) and 0.41 (3 H, s, SiMe$_A$-Me_B); δ_C(125 MHz, $CDCl_3$) 161.7+, 148.6+. 141.6+, 134.7+, 133.8−, 129.3−, 128.6−, 127.6−, 122.1−, 76.7−, 66.2−, 51.4−, 42.9+, 37.3+, 35.8−, 31.5+29.6+, 29.3+, 24.0−, 23.7−, 23.5+, 22.3−, −0.2− and −0.5−.

(2*S*,3*R*,5*S*,1′*S*,3′*R*)-3-Dimethyl(phenyl)silyl-2-(3′-3,5-dinitrobenzoyloxyclohexyl)-5-methylcyclohexanone 36

The mono ester (16 mg, 36 μmol), tetrapropylammonium perruthenate (TPAP) (13 mg, 36 μmol), *N*-methylmorpholine-*N*-oxide (NMO) (10 mg, 54 μmol) and molecular sieves (4 Å) (10 mg) were stirred in dichloromethane (1.0 cm^3) under argon at room temperature for 1 h. The mixture was filtered through a pad of silica and Celite, and the pad washed with dichloromethane (4 × 3 cm^3). The filtrate was evaporated under reduced pressure and the residue was chromatographed (SiO_2, EtOAc–light petroleum, 2 : 8) to give the *ketone* **36** (12 mg, 62%) as needles; mp 160–162 °C (from hexane–CH_2Cl_2); R_f(EtOAc–light petroleum, 3 : 7) 0.25; $\nu_{max}(CDCl_3)/cm^{-1}$ 1727, 1708 (CO), 1638 (CO), 1620 (CO), 1548 (NO_2), 1381, 1345 (NO_2), 1283 (SiMe), 1215 and 1171 (SiPh); δ_H(500 MHz, $CDCl_3$) 9.25 (1 H, t, *J* 2.1, *p*-$(NO_2)_2C_6H_3$), 9.03 (2 H, d, *J* 2.1, 2 × *o*-$(NO_2)_2C_6H_3$), 7.50 (2 H, d, *J* 6.9, 2 × *m*-Ph), 7.29 (3 H, t, *J* 7.4, 2 × *o*- and 1 × *p*-Ph), 4.31–4.29 (1 H, m, CHOCO), 2.43–2.36 (2 H, m, CH_A-H$_B$CO, CHCO), 2.30–2.01 (5 H, m, MeC*H*CH_AH$_B$CHSi, CH$_A$$H_B$CO and C$H_AH_BCHCH_AH_B$CHO), 1.98–1.93 (1 H, m, C*H*CHCO), 1.79–1.69 (2 H, m, CHSi and CH_AH$_B$CH$_A$-H$_B$CHO), 1.65–1.56 (1 H, m, MeCHCH$_A$$H_B$CHSi), 1.41–1.32 (1 H, m, CH_AH$_B$CHO), 1.29–1.15 (2 H, m, CH$_A$H$_B$CHCH$_A$-H_BCHO and CH$_A$$H_BCH_AH_B$CHO), 1.03 (3 H, d, *J* 5.8, Me), 0.93–0.79 (2 H, m, CH$_A$$H_BCH_AH_BCH_A$$H_B$CHO), 0.39 (3 H, s, Si$Me_AMe_B$) and 0.31 (3 H, s, SiMe$_A$$Me_B$); δ_C(125 MHz, $CDCl_3$) 211.4+, 161.4+, 148.6+, 139.5+, 134.6+, 133.6−, 129.3−, 128.9−, 127.8−, 122.1−, 76.3−, 59.3−, 51.6+, 35.6+, 34.6−. 34.5−, 31.5+, 30.9+, 29.7+, 28.2−, 23.4+, 22.5−, −1.5− and −1.9−; *m*/*z* (ESI) 561 (100%, $M^+ + Na^+$)(Found: M^+ + Na, 561.2035. $C_{28}H_{34}O_7N_2Si$ requires *M* + Na, 561.2033).

Crystal data for 36. $C_{28}H_{34}N_2O_7Si$, *M* = 538.66, orthorhombic, space group $P2_12_12_1$ (no. 19), *a* = 7.5858(1), *b* = 8.4440(1), *c* = 43.4801(7) Å, *U* = 2785.10(7) Å^3, *Z* = 4, μ(Mo–Kα) = 0.132 mm^{-1}, 10681 reflections measured at 180(2) K using an Oxford Cryosystems Cryostream cooling apparatus, 3281 unique (R_{int} = 0.074); R_1 = 0.042, wR_2 = 0.078 [$I>2\sigma(I)$]. The structure was solved with *SHELXS-97* and refined with *SHELXL-9*.[31] CCDC reference numbers 212800–212802. See http://www.rsc.org/suppdata/ob/b3/b305880h/ for crystallographic data in .cif or other electronic format.

(3*R*,5*R*)-5-(Dimethylphenylsilyl)-3-methyl-6-(5′-oxohexylidene)-1-trimethylsilyloxycyclohexene 34

n-Butyllithium (1.40 mol dm^{-3} solution in hexane, 0.08 cm^3, 0.112 mmol) was added to a solution of freshly distilled diisopropylamine (16 μl, 0.01 mmol) at 0 °C and the mixture stirred for 20 min, and cooled to −78 °C. The ketone **33** (35 mg, 0.10 mmol) in THF (0.5 cm^3) was added dropwise and the mixture stirred at that temperature for 1 h. Chlorotrimethylsilane (0.03 cm^3, 0.20 mmol) was added slowly and the mixture stirred for 1 h, during which time it was warmed to room temperature. The mixture was quenched with saturated sodium hydrogencarbonate (5 cm^3) and extracted with ether (3 × 5 cm^3). The combined extracts were washed with brine, dried ($MgSO_4$), and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 1 : 99 to 2 : 98) to give the *silyl enol ether* **34** (6 mg, 15%); R_f(EtOAc–light petroleum, 2 : 8) 0.6; $\nu_{max}(CDCl_3)/cm^{-1}$ 1708 (CO), 1639 (C=C), 1602, 1297, 1261 (SiMe), 1216, 1166 (SiPh), 1095 and 746; δ_H(400 MHz, $CDCl_3$) 7.52–7.32 (5 H, m, Ph), 5.60 (1 H, dd, *J* 8.8 and 5.2, C*H*=CCOTMS), 4.75 (1 H, br s, C*H*=COTMS), 2.42 (1 H, dd, *J* 5.0 and 2.2, CHSi), 2.41–2.34 (1 H, m, MeC*H*), 2.22 (2 H, dt, *J* 7.2 and 6.8, CH_2COMe), 1.89–1.82 (1 H, dd, *J* 4.8 and 2.8, CH_ACH$_B$CHSi), 1.82–1.73 (1 H, m, CH_ACH$_B$CH=C), 1.50–1.41 (3 H, m, CH$_A$CH_BCH=C and CH_2CH$_A$CH$_B$CH=C), 1.32 (1 H, ddd, *J* 24.2, 11.8 and 5.2, CH$_A$CH_BCHSi), 0.91 (3 H, d, *J* 6.8, *Me*CH), 0.32 (3 H, s, SiMe_AMe$_B$), 0.28 (3 H, s, SiMe$_A$-Me_B) and 0.21 (9 H, s, $SiMe_2$); δ_C(125 MHz, $CDCl_3$) 209.1+, 148.0+, 139.0+, 133.8−, 133.5+, 128.8−, 127.6−, 121.5−, 113.8−, 43.1+, 34.2+, 29.8−, 29.1−, 27.2+, 26.9−, 23.8+, 229−, 0.9−, −2.6− and −3.1−; *m*/*z* (ESI) 437 (100%, M^+ +

Na^+)(Found: M^+ + Na, 437.2301. $C_{24}H_{38}O_2Si_2$ requires *M* + Na, 437.2308).

(3*RS*,5*RS*)-1-*tert*-Butyldimethylsilyloxy-3-methyl-5-dimethyl-(phenyl)silylcyclohexene 38

Methyllithium (1.6 mol dm^{-3} solution in ether, 12 cm^3, 22.3 mmol) was added to a stirred suspension of copper(I) cyanide (1 g, 11.16 mmol) in THF (10 cm^3) at −40 °C and stirred for 40 min. The mixture was cooled to −78 °C and 5-trimethylsilyl-2-hexenone[45] **37** (1.5 g, 8.92 mmol) in THF (10 cm^3) was added by cannula, and the mixture stirred for 1 h. *tert*-Butylchloro(dimethyl)silane (3.3 g, 22.3 mmol) in THF (10 cm^3) was added, followed by HMPA (2.2 cm^3, 12.48 mmol) and triethylamine (3.6 cm^3, 35.6 mmol), and the mixture was stirred at −78 °C for 30 min. The mixture was warmed to room temperature and stirred for a further 1 h before being quenched carefully with basic saturated aqueous ammonium chloride. The mixture was extracted with ether (2 × 60 cm^3), and the combined extracts washed with basic saturated aqueous ammonium chloride (2 × 60 cm^3), brine (60 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 2 : 98) to give the *silyl enol ether* (2.12 g, 81%); R_f(EtOAc–light petroleum, 1.5 : 8.5) 0.88; ν_{max}(film)/cm^{-1} 1667 (C=CO) and 1249 (SiMe); δ_H(250 MHz; $CDCl_3$) 4.84 (1 H, d, *J* 4.2, HC=CO), 2.32 (1 H, m, MeC*H*), 1.85 (2 H, d, *J* 8.6, CH_2CO), 1.38–0.96 (3 H, m, MeCHCH_2 and CHSi), 0.93 (3 H, d, *J* 8, *Me*CH), 0.92 (9 H, s, $SiBu^t$), 0.12 (6 H, s, $SiMe_2$) and −0.02 (9 H, s, $SiMe_3$); δ_C($CDCl_3$) 151, 110.3, 30.6, 30.1, 28.6, 25.8, 22.8, 21.6, 18.1 and 16.8; *m*/*z* (EI) 298 (80%, M^+), 283 (100, M − Me), 241 (M − Bu^t) and 73 (20, $SiMe_3$)(Found: M^+, 298.2149. $C_{16}H_{34}OSi_2$ requires *M*, 298.2148).

(3*RS*,5*RS*,1′*E*)--5-Dimethyl(phenyl)silyl-3-methyl-2-propylidenecyclohexanone 39

The silyl enol ether **38** (0.5 g, 1.67 mmol) was added to a stirred solution of propionaldehyde (0.146 cm^3, 2.01 mmol) and titanium tetrachloride (0.1 mol dm^{-3} solution in dichloromethane, 2 cm^3, 2.01 mmol) in dichloromethane (10 cm^3) at −30 °C. The mixture was stirred for 2 h, quenched with saturated aqueous ammonium chloride and extracted with dichloromethane (2 × 20 cm^3). The extract was dried ($MgSO_4$) and evaporated under reduced pressure. The residue was diluted with toluene (20 cm^3) and *p*-toluenesulfonic acid (0.02 g) was added, and the mixture refluxed for 1 h. The mixture was poured into water and extracted with ether (2 × 60 cm^3). The combined extracts were washed with basic saturated aqueous ammonium chloride (50 cm^3), brine (50 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 6 : 94) to give the *enone* (0.189 g, 50%); R_f(EtOAc–light petroleum, 2 : 8) 0.5; ν_{max}(film)/cm^{-1} 1681 (C=O) and 1248 (SiMe); δ_H(250 MHz; $CDCl_3$) 6.39 (1 H, t, *J* 7.5, C=CH), 3.16 (1 H, m, MeC*H*), 2.43 (1 H, ddd, *J* 16.1, 4.14 and 1.8, $CH_{eq}H_{ax}CO$), 2.2–2 (3 H, m, C=CHCH_2 and $CH_{eq}H_{ax}CO$), 1.67 (3 H, m, CHSi and CH_2CHMe), 1.04 (3 H, d, *J* 7, *Me*CH), 1.04 (3 H, d, *J* 7.5, *Me*CH_2) and 0.01 (9 H, s, $SiMe_3$); *m*/*z* (EI) 222 (20%, M^+), 209 (35, M − Me), and 73 (100, $SiMe_3$)(Found: M^+, 224.1595. $C_{13}H_{24}OSi$ requires *M*, 224.1596).

(3*RS*,5*RS*)-2-(But-2′-yl)-3-methyl-5-trimethylsilyl-1-trimethylsilyloxycyclohexene 40

Methyllithium (1.6 mol dm^{-3} solution in ether, 1.25 cm^3, 2.0 mmol) was added to a stirred suspension of copper(I) cyanide (0.085 g, 0.96 mmol) in THF (10 cm^3) at −40 °C and the mixture stirred for 40 min. The mixture was cooled to −78 °C, the enone **39** (0.18 g, 0.8 mmol) in THF (10 cm^3) was added by cannula, and the mixture stirred for 1 h. Chlorotrimethylsilane (0.28 cm^3, 1.6 mmol), HMPA (0.28 cm^3, 1.6 mmol) and triethylamine (0.32 cm^3, 3.2 mmol) were added, and the mixture was stirred at −78 °C for 30 min. The mixture was allowed to warm to room temperature and stirred for a further 1 h before being quenched carefully with aqueous ammonium chloride. The mixture was extracted with ether (2 × 60 cm^3), and the combined extracts were washed with basic saturated aqueous ammonium chloride (2 × 60 cm^3), brine (60 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was chromatographed (SiO_2, EtOAc–light petroleum, 2 : 98) to give the *silyl enol ether* (0.181 g, 74%) as a 1 : 1 mixture of diastereoisomers; R_f(EtOAc–light petroleum, 2-8) 0.81; ν_{max}-(film)/cm^{-1} 1659 (C=CO) and 1250 (SiMe); δ_H(250 MHz; $CDCl_3$) 2.22 (2 H, m, MeC*H*CH_2Me), 1.89 (2 H, d, *J* 7.3, CH_2CO), 1.54–1.25 (3 H, m, CHSi and CH_2CHSi), 1.17–1.08 (2 H, m, MeCHCH_2Me), 1.03 (3 H, d, *J* 7.6, *Me*CHCH_2Me, for one isomer), 1.02 (3 H, d, *J* 7.1, *Me*CHCH_2Me, for other isomer), 1.0 (3 H, d, *J* 7, *Me*CH=C, for one isomer), 0.98 (3 H, d, *J* 7, *Me*CH=C, for other isomer), 0.87 (3 H, t, *J* 7.3, MeCH-CH_2*Me*, for one isomer), 0.81 (3 H, t, *J* 7.5, MeCHCH_2*Me*, for other isomer), 0.16 (9 H, s, $SiMe_3$, for one isomer) and −0.03 (9 H, s, $SiMe_3$, for other isomer); δ_C($CDCl_3$) 64, 60.2, 44.2, 39.5, 36.8, 33.9, 30, 29.1, 27.2, 26.6, 24.4, 22.1, 19.3, 18, 16.6, 14.5, 12.8, 10.6, 1.9, 1.3 and −3.6; *m*/*z* (EI) 312 (40%, M^+), 297 (40, M − Me) and 73 (100, $SiMe_3$)(Found: M^+, 312.2291. $C_{17}H_{36}OSi_2$ requires *M*, 312.2304).

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