Transformation of Cyclic α-Phenylthio Aldehydes by Stereoselective Aldol Reactions and Phenylthio Migration into Spirocyclic Lactones and Ethers, and *E*-Allylic Alcohols with 1,4-Related Chiral Centres

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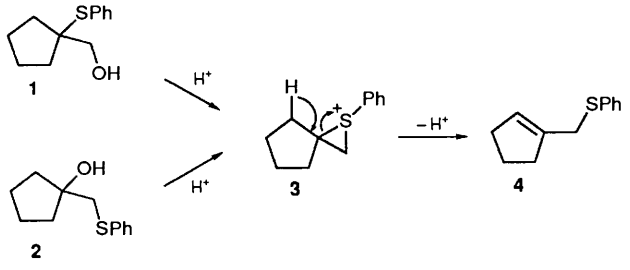
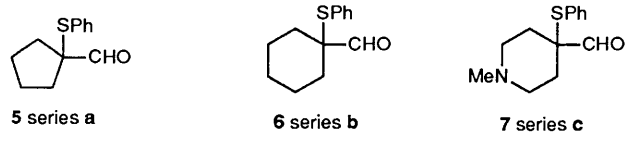
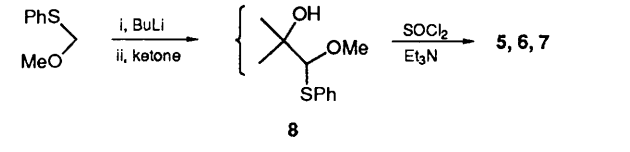
syn- and *anti*-Selective aldol reactions between enolates of propionate esters and three α-phenylthio cycloalkanecarbaldehydes give single diastereoisomers of phenylthio alcohols which rearrange in acid with 5-hydroxy or 5-CO_2H participation to give spirocyclic ethers or lactones. In the absence of internal nucleophiles, allylic sulphides are formed which are used to make allylic alcohols with an *E* double bond *exo* to the ring and two stereochemically defined 1,4-related chiral centres.

Acid-catalysed dehydration of the primary alcohol[1] **1** or the tertiary alcohol[2] **2** gives the allylic sulphide **4** *via* the common intermediate **3**. The phenylthio (PhS) migration implies stereospecific inversion at the migration terminus and we now describe[3] rearrangements of analogues of **1**, in which the migration terminus is a chiral centre, derived from α-PhS-substituted aldehydes by stereoselective aldol reactions.

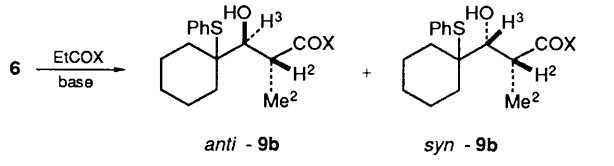


Three cyclic α-PhS-substituted aldehydes **5**–**7** were made by sulphenylation of a silyl enol ether or by rearrangement[4] of the adducts **8** from cyclopentanone, cyclohexanone, and *N*-methylpiperidin-3-one with $SOCl_2$ and base. Rearrangement of **8c**† gave a higher yield of **7** in the absence of base as it is itself a tertiary amine.



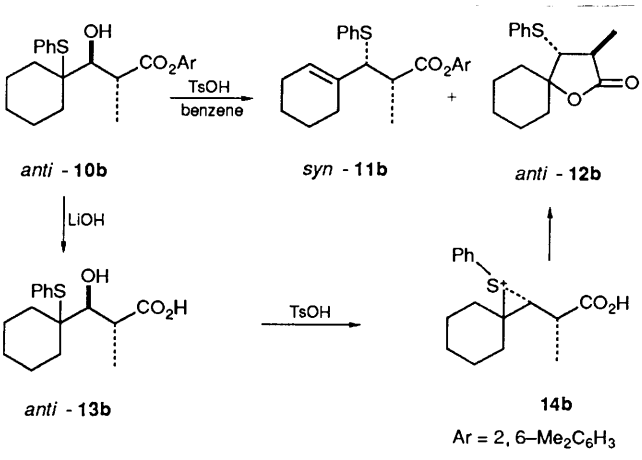


We studied aldol[5] reactions of various propionate ester enolates on aldehyde **6** (Table 1) and selected the lithium enolate of the 2,6-dimethylphenyl ester[5,6] and the boron enolate of the phenylthioester[5,7] as the most efficient way to make the *anti* and *syn* aldols respectively (Scheme 1). The former method was then applied to the other two aldehydes **5** and **7** to give high yields of *anti*-**10a** and *anti*-**10c**. Aldols are unambiguously defined as *syn* or *anti* in the usual way.[5] It seems logical to retain this system for the spirocyclic compounds even though the arrangement of the chain in a ring instead of an extended conformation means that *anti*-**13** to *anti*-**12** is an inversion.



Scheme 1

Aldol stereochemistry was confirmed by NMR spectroscopy. Most *syn* aldols show a lower $J^{2,3}$-value than do *anti* aldols but products from large aldehydes (*e.g.*, Bu^{t}CHO) show small $J^{2,3}$-values for both isomers.[5] The ^{13}C NMR shifts of C-3 (CHOH) and Me^2 in *syn* and *anti*-**9** are more reliable[8] (Table 2).



Rearrangement of the *anti* 2,6-dimethylphenyl esters **10** with toluene-*p*-sulphonic acid (TsOH) in benzene gave a mixture of the allylic sulphides **11** and the lactones **12**. In series **b**, higher yields of lactone **12** were obtained by hydrolysis (LiOH, water, MeOH) and rearrangement of the free acid **13**. The intermediate **14** and the product **12** are the same as those of sulphenyllactonisation[9] in which γ-lactones are the thermodynamic though not the kinetic products. These lactones **12** are formed stereospecifically with inversion at C-3: *anti*-**13b** gives *anti*-**12b**, while *syn*-**13b** gives *syn*-**12b**. The lactones show characteristic[10] $J^{2,3}$-values in the ^1H NMR spectrum: 12.2 Hz for *anti*-**12b** and 8.9 Hz for *syn*-**12b**.

The rearrangement of *anti*-**10c** was much slower (3 h in CH_2Cl_2) and gave pure crystalline **12c** in 80% yield without chromatography. The slow loss of H^A from the intermediate **16**

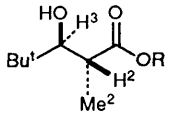
† Compounds derived from aldehyde **5** are numbered **a** those from **6** are numbered **b**, and those from **7**, **c**.

Table 1 Stereoselective aldol reactions on cyclic α-PhS aldehydes (Scheme 1)

Aldehyde	X	Reagents	Product	*anti-syn* Ratio	Products isolated (%) *anti*	*syn*
6	OMe	LDA	**9b**	35:65	27	50
6	OMe	*i*, LDA *ii*, cp_2ZrCl_2 [a]	**9b**	30:70		59
6	SPh	9-BBN-OTf Pr^i_2NEt	**9b**	5:95		76
6	OAr[b]	LDA	**11b**	95:5	84	
5	OAr[b]	LDA	**11a**	96:4	70	
7	OAr[b]	LDA	**11c**	95:5	72	

[a] See ref. 20. [b] Ar = 2,6-dimethylphenyl, see refs. 5 and 6.

Table 2 Stereochemistry of aldols (see Scheme 1)

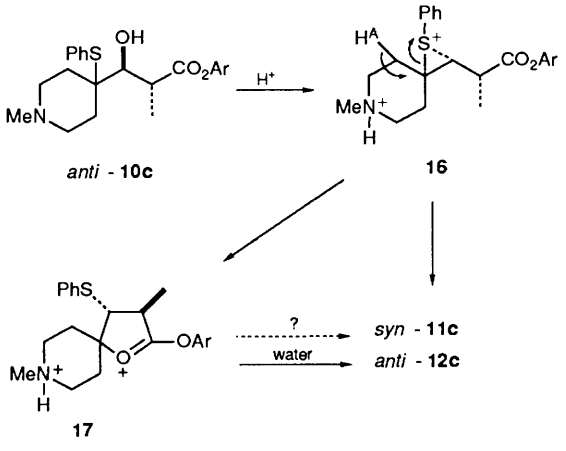


anti - **15**

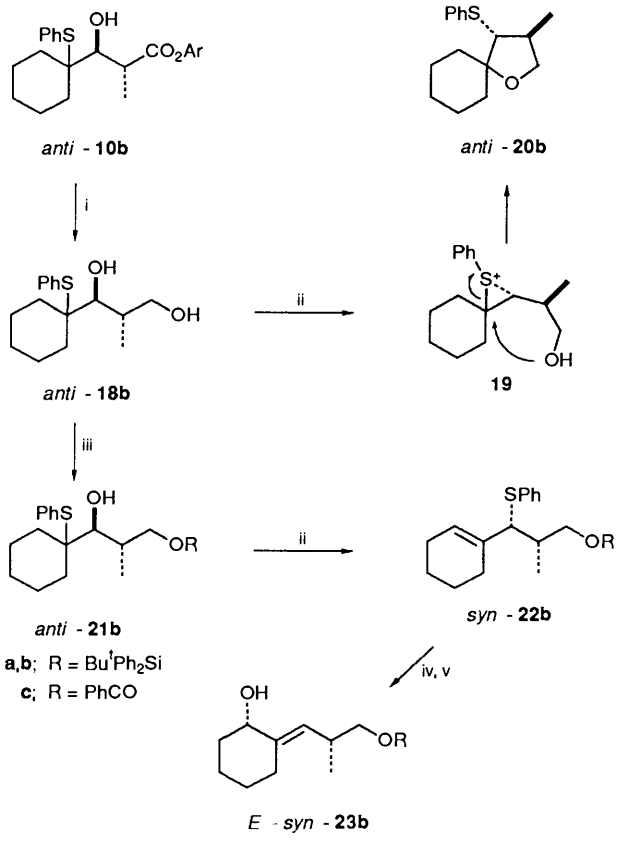
Aldol	$J^{2,3}$ (Hz)	$\delta_C(Me^2)$
anti-**10a**	4.3	16.6
anti-**9b**	2.3	16.7
anti-**9c** (X = Ar)[a]	2.4	16.7
anti-**15** (R = Ar[a])[b]	3.0	16.6
anti-**15** (R = Me)[b]	2.0	17.9
anti-**9b** (X = OMe)	1.8	18.0
syn-**9b** (X = OMe)	5.6	14.2
syn-**9b** (X = SPh)	5.4	15.2
syn-**15** (R = Me)[b]	3.0	12.8

[a] Ar = 2,6-dimethylphenyl. [b] See refs. 5 and 8.

(which reinforces our explanation [2] of the regioselectivity of allyl sulphide formation in similar compounds) gives time for the efficient capture of the intermediate **17** by the molecule of water released in the formation of intermediate **16**.



Reduction of any aldol from Table 1 with $LiAlH_4$ gave the corresponding diol **18** (Scheme 2) with no loss of stereochemistry. Rearrangement in acid gave the spirocyclic ethers **20** stereospecifically in excellent yield. The nearest analogy is Williams' cyclisation [11] (without PhS migration) of some tertiary alcohols giving tetrahydrofurans by *endo* attack on an episulphonium ion (*cf.* **18b** in Scheme 2). The stereochemistry of

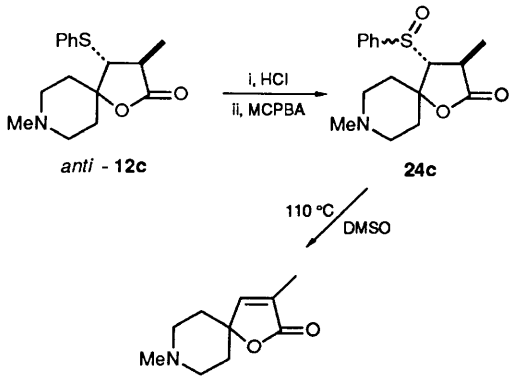


Scheme 2 *Reagents*: i, $LiAlH_4$; ii, TsOH; iii, RCl, base; iv, $NaIO_4$; v, PhS^-, MeOH

the ethers **20** could not be determined by coupling constants as *e.g.*, the two diastereotopic protons at C-2 in *anti*-**20b** are each triplets showing that $J_{gem} = J^{2,3}{}_{syn} = J^{2,3}{}_{anti}$. However, NOE studies allowed correlation of one of these protons to the methyl group and then to the proton at C-4, confirming inversion at C-4 in both isomers of **20b**. Experiments in open-chain compounds [12] with a chiral migration origin (C-4) show that both cyclisations occur with inversion at that centre also.

Allyl sulphide formation occurred in high yield after chemoselective protection of the primary alcohol of the diol **18** either as a t-butyldiphenylsilyl ether **21a,b** or a benzoate **21c**. We now prefer the benzoate as it is less susceptible to cleavage under the rearrangement conditions. Rearrangement of *anti*-**21a–c** gave *syn*-**22** in high yield while *syn*-**21b** gave *anti*-**22b** under the same conditions. The rearrangement of the *syn* compound is faster and the product (*anti*-**22b**) is not susceptible to epimerisation. *Anti*-**21**, however, must be rearranged in the absence of light and oxygen (preferably under argon) to avoid epimerisation of *syn*-**22**, probably by a [1,3]PhS shift.[13]

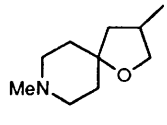
Removal of PhS *from the Rearrangement Products.*—We have already shown[14] that β-PhS butanolides, such as **12**, give butenolides in high yield on oxidation and thermolysis. The only unusual example from lactones **12** was the amino compound **12c** and this indeed gave a poor yield of the sulphoxide by direct oxidation. Fortunately, prior conversion into the hydrochloride allowed clean formation of the sulphoxide **24c** and hence the butenolide **25c**. Williams[11] has used reductive removal of PhS from tetrahydrofurans and so *syn*- or *anti*-**20** are precursors for spiro compounds **26**.



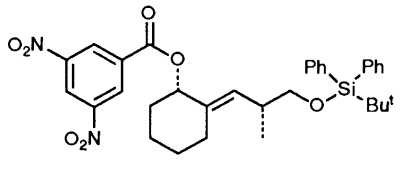
anti - **12c** **24c** **25c**

The allylic sulphides **22** are more interesting, as the corresponding sulphoxides give [2,3] sigmatropic rearrangements[15] which are stereospecifically suprafacial: *syn*-**22** gives *syn*-**23** and *anti*-**22b** gives *anti*-**23b**, both with 1,4-related chiral centres. They are also stereoselective: both diastereoisomers are formed with an *E* double bond. Stork has used similar sulphoxide rearrangements in prostaglandin synthesis,[16] and Heathcock[17] has used [3,3] sigmatropic rearrangements to translate aldol stereochemistry into 1,4- and 1,5-related chiral centres. We have now extended our work to open-chain compounds.[12]

The *syn* and *anti* products **23b** (R = Bu^{t}Ph$_2$Si) are almost identical by ^{1}H and ^{13}C NMR spectroscopy (which at least confirms the *E*-stereochemistry). The free diols **23b** (R = H), made either by desilylation of compound **23b** with fluoride or by reduction of the ester **11b** to the alcohol **22b** (R = H) and [2,3] rearrangement, had slightly different ^{1}H NMR spectra, but the 3,5-dinitrobenzoates **27** established conclusively that each isomer was free from the other as, *e.g.*, δ(Bu^t) = 0.94 (*anti*) and 1.03 (*syn*).



26c



E - *syn* **27**

Experimental

1-*Trimethylsiloxycyclohexylidenemethane.*—The silyl enol ether was prepared from cyclohexanecarbaldehyde (10 g, 89 mmol) by the method of Stang *et al.*,[18] and gave the silyl enol ether (14.41 g, 88%) as an oil, b.p. 86–87 °C/18 mmHg (lit.,[18] b.p. 75–76 °C/12 mmHg); $\delta_H(CDCl_3)$ 5.89 (1 H, br s, C=C*H*OSiMe$_3$), 2.08 (2 H, t, *J* 5.4 Hz, CH_2C=C), 1.84 (2 H, t, *J* 5.4 Hz, CH_2C=C), 1.41–1.30 (6 H, m, $[CH_2]_3$) and 0.06 (9 H, s, SiMe$_3$); ν_{max}(liquid film) 1680 cm^{-1} (C=C).

1-*Phenylthiocyclohexanecarbaldehyde* **6.**—Benzenesulphenyl chloride (21.5 cm^3, 2.0 mol dm^{-3} in CH_2Cl_2; 43 mmol) was added slowly to a solution of the above silyl enol ether (8 g, 43 mmol) in dry CH_2Cl_2 (10 cm^3) under nitrogen at −78 °C. The mixture was allowed to warm to room temperature and solvent was removed under reduced pressure. The residue was distilled to give the aldehyde (9.50 g, 98%) as an oil, b.p. 131–132 °C/0.2 mmHg; $\delta_H(CDCl_3)$ 9.24 (1 H, s, C*H*O), 7.51–7.24 (5 H, m, SPh) and 1.89–1.25 (10 H, m, $[CH_2]_5$) [lit.,[19] $\delta_H(CDCl_3)$ 9.28 (1 H, s, CHO)].

4-[*Methoxy*(*phenylthio*)*methyl*]-1-*methylpiperidin*-4-*ol* **8c.**—Butyllithium (34.7 cm^3 of a 1.55 mol dm^{-3} solution in hexane, 53.7 mmol) was slowly added to a solution of methoxymethyl phenyl sulphide[4] (7.5 cm^3, 51.3 mmol) in dry tetrahydrofuran (THF) (80 cm^3) under argon at −30 °C. After 40 min, a solution of 1-methyl-4-piperidone (6.0 cm^3, 48.8 mmol) in dry THF (65 cm^3) was added. After a further 20 min at −30 °C, the solution was poured into saturated aq. ammonium chloride (100 cm^3), basified (NaOH), and extracted with CH_2Cl_2 (3 × 120 cm^3). The combined extracts were dried ($MgSO_4$) and evaporated. The residue was recrystallised from CH_2Cl_2–light petroleum (b.p. 60–80 °C) to give the *amino alcohol* **8c** (10.5 g) as needles, m.p. 96–97 °C; R_f [ethyl acetate–methanol–triethylamine (66:33:1)] 0.20; $\nu_{max}(CHCl_3)$/cm^{-1} 3570 (OH) and 1580 (SPh); $\delta_H(CDCl_3)$ 7.51–7.47 (2 H, m, Ph), 7.31–7.20 (8 H, m, Ph), 4.46 (1 H, s, C*H*SPh), 3.41 (3 H, s, OMe), 2.68–2.63 (2 H, m, NCH_2), 2.42 (1 H, br s, OH), 2.36–2.24 (2 H, m, NCH_2), 2.28 (3 H, s, NMe), 1.99 (1 H, dt, *J* 13.2 and 4.5 Hz, NCH_2CH*H*^{ax}), 1.92 (1 H, dt, *J*/Hz: 13.2 and 4.5, NCH_2CH*H*^{ax}), 1.70 (1 H, dd, *J*/Hz: 13.4 and 2.6, NCH_2CH*H*^{eq}) and 1.59 (1 H, dd, *J*/Hz: 13 and 2.6, NCH_2CH*H*^{eq}); $\delta_C(CDCl_3)$ 135.83, 132.76, 129.07, 127.34, 102.89, 72.10, 57.61, 51.21, 50.98, 46.09, 33.23 and 33.06; *m*/*z* 267 (14%, M$^+$), 252 (55, M − Me), 158 (80, M − SPh), and 70 (100, C_4H_8N) (Found: C, 62.6; H, 7.85; N, 5.1; S, 12.3%; M$^+$, 267–1294. $C_{14}H_{21}NO_2S$ requires C, 62.9; H, 7.9; N, 5.2; S, 12.0%; M, 267–1294).

1-*Methyl*-4-*phenylthiopiperidine*-4-*carbaldehyde* **7.**—Thionyl chloride (2.5 cm^3, 34 mmol) was added to a solution of the alcohol **8c** (3.0 g, 11.2 mmol) in CH_2Cl_2 (20 cm^3) under argon at 0 °C. The solution was stirred for 60 min, poured into water (50 cm^3), basified (NaOH), and extracted with CH_2Cl_2 (4 × 50 cm^3). The combined extracts were dried ($MgSO_4$), evaporated, and purified by column chromatography on silica gel (250 g), eluting with ethyl acetate–methanol–triethylamine (94:5:1), to give the *aldehyde* (2.43 g, 92%) as an oil, R_f[ethyl acetate–methanol–triethylamine (94:5:1) 0.30; $\nu_{max}(CDCl_4)$/cm^{-1} 1710 (C=O) and 1580 (SPh); $\delta_H(CDCl_3)$ 9.23 (1 H, s, CHO), 7.38–7.24 (5 H, m, Ph), 2.75–2.66 (2 H, m, NCH_2^{eq}), 2.24 (3 H, s, NMe), 2.15–2.06 (2 H, m, NCH_2ax) and 1.99–1.79 (4 H, m, NCH_2CH_2); $\delta_C(CDCl_3)$ 193.88, 137.00, 129.57, 128.91, 128.56, 57.44, 52.23, 45.93 and 30.14 (Found: M$^+$ − CO, 207.1071. $C_{12}H_{17}NS$ requires M − CO, 207.1082); *m*/*z* 207 (3%, M − SPh) and 83 (100, C_5H_9N).

(2RS,3SR)-2,6-*Dimethylphenyl* 3-*Hydroxy*-2-*methyl*-3-[1-(*phenylthio*)*cyclohexyl*]*propionate*, anti-**10b.**—A solution of 2,6-dimethylphenyl propionate[6] (0.935 g, 5.25 mmol) in THF (10 cm^3) was added dropwise to a solution of lithium diisopropylamide (LDA) (5.5 mmol) in THF (30 cm^3) during 15 min at −78 °C under argon. After 10 min the aldehyde **6** (1.1 g, 5 mmol) was added and the mixture was stirred for 5 min

before the reaction was quenched with saturated aq. ammonium chloride (2 cm^3) at −78 °C. After the mixture had warmed to room temperature, saturated aq. ammonium chloride (100 cm^3) was added, the organic phase was separated, and the aqueous layer was extracted with diethyl ether (2 × 50 cm^3). The combined organic fractions were washed with brine (50 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was recrystallised from diethyl ether–hexane to give the *hydroxy ester* **10b** (1.68 g, 84%) as prisms, m.p. 101–102 °C; $R_f(CH_2Cl_2)$ 0.37; ν_{max}(Nujol)/cm^{-1} 3450 (sharp, OH) and 1705 (C=O); $\delta_H(CDCl_3)$ 7.53–7.31 (5 H, m, SPh), 7.06 (3 H, s, OAr), 4.32 (1 H, d, *J* 8.3 Hz, CHO*H*), 3.81 (1 H, dq, *J*/Hz 7.4 and 2.3, C*H*Me), 3.38 (1 H, dd, *J*/Hz 8.3 and 2.3, C*H*OH), 2.19 (6 H, s, $ArMe_2$), 1.99–1.52 (10 H, m, C_6H_{10}) and 1.58 (3 H, d, *J* 7.4 Hz, Me); $\delta_C(CDCl_3)$ 175.06, 147.78, 137.09, 130.86, 130.26, 128.93, 128.80, 126.01, 79.33, 60.10, 38.15, 30.70, 25.83, 21.83, 21.76, 18.82 and 16.70 (Found: M^+ − PhS, 289.1802. $C_{18}H_{25}O_3$ requires M − C_6H_5S, 289.1798; *m/z* 289 (3%, M^+ − PhS), 149 (35, $Me_2C_6H_3CO_2$), and 121 (100, $Me_2C_6H_3CO$) (Found: C, 72.6; H, 7.5; S, 8.0. $C_{24}H_{30}O_3S$ requires C, 72.4; H, 7.5; S, 8.0%).

(2RS,3SR)-2,6-*Dimethylphenyl* 3-*Hydroxy*-2-*methyl*-3-[1-(*phenylthio*)*cyclopentyl*]*propionate*, anti-**10a**.—In the same way, 2,6-dimethylphenyl propionate[6] (1.0 g) and the aldehyde[4] **5** (1.11 g) gave a 96:4 mixture of diasteroisomers, crystallised from hexane to give the *ester* **10a** (1.46 g, 70%) as cubes, m.p. 112–114 °C; R_f[CH_2Cl_2–hexane (9:1)] 0.51; ν_{max}(Nujol)/cm^{-1} 3650–3350 (OH) and 1720 (C=O); $\delta_H(CDCl_3)$ 7.59–755 (2 H, dd, ArH, *o* to S), 7.37–7.30 (3 H, m, ArH), 7.06 (3 H, s, ArH), 3.80–3.72 (1 H, br, OH), 3.75 (1 H, m, C*H*CO_2Ar), 3.68 (1 H, d, *J* 4.3 Hz, C*H*OH), 2.20 (6 H, s, ArMe), 2.00–1.70 (8 H, m, $[CH_2]_4$) and 1.51 (3 H, d, *J* 7.2 Hz, Me); $\delta_C(CDCl_3)$ 174.5, 147.8, 136.7, 132.4, 130.3, 128.8, 128.7, 125.9, 79.5, 66.7, 41.4, 35.4, 34.7, 24.0, 23.9, 17.8 and 16.6 (Found: M^+, 384.1747. $C_{23}H_{28}O_3S$ requires M, 384.1759); *m/z* 384 (4%, M^+), 263 (100, M − $Me_2C_6H_3O$), 177 (48, $Me_2C_6H_3CO_2CHMe$), 122 (45, $Me_2C_6H_3OH$) and 97 (52, C_5H_8CHO).

(2RS,3SR)-2,6-*Dimethylphenyl* 3-*Hydroxy*-2-*methyl*-3-[4′-(1′-*methyl*-4′-(*phenylthio*)*piperidyl*)]*propionate*, anti-**10c**.—In the same way, 2,6-dimethylphenyl propionate[6] (2.0 g, 11.2 mmol) and the aldehyde **7** (2.5 g, 10.6 mmol) gave the *ester* (3.16 g, 72%), purified by column chromatography on silica gel (200 g) eluting with ethyl acetate–methanol–triethylamine (94:5:1), as cubes, m.p. 115–116 °C; R_f[ethyl acetate–methanol–triethylamine (94:5:1)] 0.21; $\nu_{max}(CHCl_3)$/cm^{-1} 3460 (OH), 1725 (C=O) and 1580 (SPh); $\delta_H(CDCl_3)$ 7.53–7.50 (5 H, m, Ph), 7.05 (3 H, s, OAr), 4.28 (1 H, d, *J* 8.1 Hz, OH), 3.78 (1 H, dq, *J*/Hz 7.3 and 2.6, C*H*Me), 3.48–3.45 (1 H, dd, *J*/Hz 7.8 and 2.4, C*H*OH), 2.73–2.59 (4 H, m, NCH_2), 2.34 (3 H, s, NMe) and 2.31–2.04 (2 H, m, NCH_2CH_2); $\delta_C(CDCl_3)$ 174.61, 147.75, 137.24, 130.21, 129.10, 128.91, 128.74, 125.99, 79.13, 57.33, 51.28, 51.20, 46.20, 38.45, 30.29, 18.73 and 16.69 (Found: M^+ − PhS, 304.1890. $C_{18}H_{26}NO_3$ requires M − C_6H_6S, 304.1913); *m/z* 304 (100%, M − PhS and $Me_2C_6H_3OH$) and 122 (61, $Me_2C_6H_3OH$) (Found: C, 69.9; H, 7.8; N, 3.4; S, 8.0. $C_{24}H_{31}NO_3S$ requires C, 69.7; H, 7.55; N, 3.4; S, 7.75%).

Methyl 3-*Hydroxy*-2-*methyl*-3-[1-(*phenylthio*)*cyclohexyl*]-*propionate* **9b** (X = Me).—A solution of methyl propionate (1.58 g, 18 mmol) in THF (20 cm^3) was added dropwise to a solution of LDA (16.5 mmol) in THF (50 cm^3) at −78 °C under argon. After 20 min, a solution of the aldehyde **6** (3.3 g, 15 mmol) in THF (2 cm^3) was added, and the mixture was stirred for 2 h at −78 °C and then quenched with aq. ammonium chloride (10 cm^3) at −78 °C. Water (10 cm^3) was added, the organic layer was separated, and the aqueous layer was extracted with diethyl ether (2 × 50 cm^3). The combined organic extracts were dried ($MgSO_4$), evaporated under reduced pressure, and purified by column chromatography eluting with CH_2Cl_2 to give the *aldol* syn-**9b** (X = OMe) (1.87 g, 50%) as an oil, $R_f(CH_2Cl_2)$ 0.2; ν_{max}(film)/cm^{-1} 3450 (OH), 1710 (C=O) and 1580 (SPh); $\delta_H(CDCl_3)$ 7.53–7.25 (5 H, m, SPh), 3.77 (1 H, dd, J_{34} 4.3, J_{32} 5.6 Hz, CH^3OH), 3.61 (3 H, s, OMe), 2.99 (1 H, dq, *J* 7.0, J_{23} 5.6 Hz, CH^2Me), 2.92 (1 H, d, J_{43} 4.2 Hz, CH^3OH), 1.91–1.21 (10 H, m, C_6H_{10}) and 1.27 (3 H, d, *J* 7.0 Hz, CH^2Me); $\delta_C(CDCl_3)$ 176.79, 137.09, 130.49, 129.01, 128.83, 74.74, 61.41, 51.73, 40.58, 31.35, 30.74, 25.93, 21.96 and 14.15 (Found: M^+, 308.1469. $C_{17}H_{24}O_3S$ requires M, 308.1445); *m/z* 308 (5%, M^+), 221 (14, M − $C_3H_7O_2$), 199 (13, M − PhS), 191 (64, M − $C_5H_9O_3$), 111 (73), 110 (55, PhSH), and 81 (100); and the (2RS,3SR)-*aldol* anti-**9b** (X = OMe) (1.02 g, 27%) as plates, m.p. 57–59 °C (from diethyl ether–hexane); $R_f(CH_2Cl_2)$ 0.28; ν_{max}(film)/cm^{-1} 3450 (OH), 1710 (C=O) and 1580 (SPh); $\delta_H(CDCl_3)$ 7.48–7.25 (5 H, m, SPh), 4.24 (1 H, d, J_{43} 8.7, CH_2OH), 3.71 (3 H, s, OMe), 3.50 (1 H, dq, J_{23} 1.8, *J* 7.3 Hz, CH_2Me), 3.27 (1 H, dd, J_{32} 1.8, J_{34} 8.7 Hz, CH^3OH), 2.10–1.55 (10 H, m, C_6H_{10}) and 1.33 (3 H, d, *J* 73. Hz, CH^2Me); $\delta_C(CDCl_3)$ 178.06, 137.05, 131.16, 128.77, 128.70, 79.67, 59.55, 51.89, 37.38, 31.18, 30.22, 25.79, 22.00, 21.80 and 17.97 (Found: M^+, 308.1461. $C_{17}H_{24}O_3S$ requires M, 308.1446); *m/z* 308 (4%, M^+), 191 (100, M − $C_5H_9O_3$), 111 (58), 110 (77, PhSH) and 81 (68).

(2RS,3RS)-3-*Hydroxy*-2-*methyl*-3-[1-(*phenylthio*)*cyclohexyl*]*propionic Acid*, syn-**13b**.—Lithium hydroxide monohydrate (200 mg, 4.2 mmol) was added to a solution of the ester *syn*-**9b** (X = OMe) (170 mg, 0.55 mmol) in methanol (3 cm^3)–water (1 cm^3) and the mixture was stirred for 24 h. Aq. sodium carbonate (3 cm^3), aq. sodium hydroxide (1 cm^3), and water (10 cm^3) were added and the solution was extracted with chloroform (5 cm^3). The aqueous layer was acidified with hydrochloric acid and ice and extracted with chloroform (3 × 5 cm^3), dried ($MgSO_4$), and evaporated under reduced pressure. The residue was recrystallised from chloroform–hexane to give the *acid* **13b** (152 mg, 94%) as needles, m.p. 147–148 °C; R_f[MeOH–CH_2Cl_2 (1:9)] 0.27; ν_{max}(Nujol)/cm^{-1} 3350 (OH, sharp), 3000 (CO_2H) and 1695 (C=O); $\delta_H(CDCl_3)$ 7.53–7.27 (5 H, m, Ph), 3.80 (1 H, d, *J* 4.8 Hz, C*H*OH), 3.02 (1 H, dq, *J*/Hz 4.8 and 7.2 C*H*Me), 1.95–1.20 (10 H, m, C_6H_{10}) and 1.32 (3 H, d, *J* 7.2 Hz, CHMe) (Found: M^+, 294.1267. $C_{16}H_{22}O_3S$ requires M, 294.1284); *m/z* 294 (5%, M^+), 191 (45, $C_6H_{10}SPh$), 185 (4, M − SPh), 110 (75, PhSH) and 81 (100, C_6H_9).

Rearrangement of (2RS,3SR)-2,6-*Dimethylphenyl* 3-*Hydroxy*-2-*methyl*-3-[1-(*phenylthio*)*cyclohexyl*]*propionate*, anti-**10b**.—The ester *anti*-**10b** (398 mg, 1.0 mmol) was refluxed in benzene in a foil-wrapped flask (5 cm^3) under argon, a refluxing solution (2 cm^3) of TsOH in dry benzene (100 mg in 10 cm^3) was added, and the mixture was refluxed for a further 10 min. The solution was cooled in ice, passed through a short silica column with CH_2Cl_2 as eluant, and the solvents were removed under reduced pressure. Purification by column chromatography on silica gel and elution with CH_2Cl_2 gave (2RS,3SR)-2,6-*dimethylphenyl* 3-(*cyclohex*-1-*enyl*)-2-*methyl*-3-(*phenylthio*)-*propionate*, syn-**11b** (242 mg, 63%) as an oil, $R_f(CH_2Cl_2)$ 0.70; ν_{max}(film)/cm^{-1} 1750 (C=O), 1650 (C=C) and 1580 (SPh); $\delta_H(CDCl_3)$ 7.42–7.24 (5 H, m, SPh), 7.03 (3 H, s, OAr), 5.28 (1 H, br s, CH=C), 3.77 (1 H, d, *J* 11.1 Hz, C*H*SPh), 3.10 (1 H, dq, *J*/Hz 11.1 and 6.9, C*H*Me), 2.27–2.24 (4 H, m), 2.12 (6 H, s, $ArMe_2$), 1.86–1.46 (4 H, m, CH_2CH_2), and 1.66 (3 H, d, *J* 6.9 Hz, CH*Me*) (Found: M^+, 380.1793. $C_{24}H_{28}O_2S$ requires M, 380.1803); *m/z* 380 (0.6%, M^+), 271 (2.5, M − PhS), and 121 (100, $C_6H_3Me_2O$); and (3RS,4SR)-3-*methyl*-4-*phenylthio*-1-*oxaspiro*[3,4]*decan*-2-*one*, anti-**12b** (90 mg, 32%) as needles,

m.p. 105–106 °C (from diethyl ether–hexane); $R_f(CH_2Cl_2)$ 0.38; ν_{max}(Nujol)/cm^{-1} 1770 (C=O) and 1580 (SPh); $\delta_H(CDCl_3)$ 7.51–7.25 (5 H, m, SPh), 3.11 (1 H, d, *J* 12.2 Hz, C*H*SPh), 2.68 (1 H, dq, *J*/Hz 12.2 and 7.0, C*H*Me), 1.91–1.14 (10 H, m, C_6H_{10}), and 1.28 (3 H, d, *J* 7.0 Hz, CH*Me*); $\delta_C(CDCl_3)$ 176.16, 134.17, 132.83, 129.33, 128.11, 86.67, 62.23, 41.55, 36.27, 31.73, 25.11, 22.42, 21.49 and 13.82 (Found: M$^+$, 276.1193. $C_{16}H_{20}O_2S$ requires M, 276.1179); *m*/*z* 276 (5%, M$^+$), 150 (100, M − $C_6H_{10}CO_2$), 135 (50), 110 (20, HSPh) and 69 (52).

(3RS,4RS)-3-*Methyl*-4-*phenylthio*-1-*oxaspiro*[4.5]*decan*-2-*one*, syn-**12b**.—In the same way, the acid *syn*-**13b** (42 mg, 0.14 mmol) with catalytic TsOH (5 mg) gave the *lactone* **12b** (34 mg, 86%) as an oil, $R_f(CH_2Cl_2)$ 0.5; ν_{max}(film)/cm^{-1} 1760 (lactone) and 1580 (SPh); $\delta_H(CDCl_3)$ 7.50–7.19 (5 H, m, SPh), 3.80 (1 H, d, *J* 8.9 Hz, C*H*SPh), 3.10 (1 H, dq, *J*/Hz 8.9 and 7.6, C*H*Me), 1.93–1.20 (10 H, m, C_6H_{10}) and 1.38 (3 H, d, *J* 7.6 Hz, CH*Me*); $\delta_C(CDCl_3)$ 177.31, 135.34, 130.77, 130.66, 127.14, 87.10, 57.95, 39.36, 36.89, 34.23, 24.89, 22.69, 22.03 and 13.69 (Found: M$^+$, 276.1180. $C_{16}H_{20}O_2S$ requires M, 276.1184); *m*/*z* 276 (25%, M$^+$) and 150 (100, M − $C_6H_{10}CO_2$).

(3RS,4SR)-3-*Methyl*-4-(*phenylthio*)-1-*oxaspiro*[4.4]*nonan*-2-*one*, anti-**12a**.—Aq. sodium hydroxide (30%; 0.4 cm^3) was added to a solution of the ester *anti*-**10a** (205 mg) in methanol (6 cm^3) and the solution was stirred at room temperature for 2.25 h, then poured into brine (25 cm^3), acidified with sulphuric acid (1.5 mol dm^{-3}), and extracted with ethyl acetate (3 × 15 cm^3). The combined extracts were dried ($MgSO_4$), and evaporated under reduced pressure. The residue was dissolved in benzene (1 cm^3) and TsOH (10 mg) was added. The solution was heated under reflux for 5 min, allowed to cool to room temperature, and filtered through silica gel (elution with CH_2Cl_2). The filtrate was evaporated under reduced pressure to give the *lactone* **12a** (15 mg, 13%) as an oil, R_f[hexane–diethyl ether (2:1)] 0.37; ν_{max}(film)/cm^{-1} 1765 (C=O); $\delta_H(CDCl_3)$ 7.50–7.45 (5 H, m, Ph), 3.42 (1 H, d, *J* 12.2 Hz, C*H*SPh), 2.63 (1 H, dq, *J*/Hz 12.2 and 7.0, $CHCO_2R$), 2.27–1.53 (8 H, m, $[CH_2]_4$) and 1.28 (3 H, d, *J* 7.0 Hz, Me) (Found: M$^+$, 262.1031. $C_{15}H_{18}O_2S$ requires M, 262.1028); *m*/*z* 262 (22%, M$^+$) and 150 (100, PhSCHCHMe).

(3RS,4SR)-3,8-*Dimethyl*-4-*phenylthio*-8-*aza*-1-*oxaspiro*[4.5]-*decan*-2-*one*, anti-**12c**.—The ester *anti*-**10c** (0.2 g, 0.48 mmol) and TsOH (0.65 g, 3.4 mmol) were heated in CH_2Cl_2 (1.5 cm^3) under reflux under argon for 3 h. CH_2Cl_2 (10 cm^3) and water (10 cm^3) were added, and the solution was basified (NaOH) and extracted with CH_2Cl_2 (3 × 15 cm^3). The combined extracts were dried (Na_2SO_4) and evaporated. The residue was recrystallised from CH_2Cl_2–hexane to give the *spirolactone* **12c** (0.113 g, 80%) as needles, m.p. 116–118 °C; R_f[ethyl acetate–methanol–triethylamine (74:25:1)] 0.36; $\nu_{max}(CHCl_3)$/cm^{-1} 1760 (C=O) and 1580 (SPh); $\delta_H(CDCl_3)$ 7.51–7.47 (2 H, m, Ph), 7.36–7.28 (3 H, m, Ph), 3.14 (1 H, d, *J* 12.4 Hz, C*H*SPh), 2.82–2.59 (3 H, m, C*H*Me and NCH_2), 2.41–2.32 (3 H, m, NCH_2 and NCH_2CH), 2.30 (3 H, s, NMe), 1.96 (1 H, dt, *J*/Hz 13.2 and 5.0, NCH_2CH*H*^{ax}), 1.64 (1 H, m, NCH_2CH*H*^{eq}), 1.50 (1 H, dd, *J*/Hz 13.8 and 2.6, NCH_2CH*H*^{eq}) and 1.33 (3 H, d, *J* 7.0 Hz, CH*Me*); $\delta_C(CDCl_3)$ 175.85, 133.78, 129.37, 128.19, 84.22, 61.30, 51.61, 50.77, 46.05, 41.18, 35.51, 31.36 and 13.62; *m*/*z* 291 (56%, M), 181 (40, M − PhS), and 70 (100, C_4H_8N) (Found: C, 66.2; H, 7.3; N, 4.95; S, 10.9%; M$^+$, 291.1284. $C_{16}H_{21}NO_2S$ requires C, 65.95; H, 7.25; N, 4.8; S, 11.0%; M, 291.1293).

(1RS,2RS)-2-*Methyl*-1-[1-(*phenylthio*)*cyclohexyl*]*propane*-1,3-*diol*, anti-**18b**.—Lithium aluminium hydride (304 mg, 8.0 mmol) was added to a solution of the ester *anti*-**10b** (1.707 g, 4.27 mmol) in dry diethyl ether (30 cm^3) at 0 °C. After 4 h, the mixture was quenched with ice, diluted with aq. sodium hydroxide (20 cm^3) and aq. sodium potassium tartrate (200 cm^3), and extracted with diethyl ether (3 × 100 cm^3). The combined extracts were dried ($MgSO_4$), evaporated under reduced pressure, and purified by column chromatography, eluting with methanol–CH_2Cl_2 (1:25). Recrystallisation from ethyl acetate gave the *diol* **18b** (1.064 g, 89%) as needles, m.p. 120.5–121 °C; R_f[methanol–CH_2Cl_2 (1:25)] 0.4; ν_{max}(Nujol)/cm^{-1} 3360 (sharp, OH) and 3300 br (OH); $\delta_H(CDCl_3)$ 7.50–7.25 (5 H, m, SPh), 3.68* (1 H, dd, J_{AB} 11.2, J_{AX} 3.9 Hz, CH_AH_BOH), 3.63* (1 H, dd, J_{BA} 11.2, J_{BX} 6.3 Hz, CH_AH_BOH), 3.21* (1 H, d, *J* 4.8 Hz, C*H*OH), 2.04–1.17 (11 H, m, C_6H_{10} and CH_XMe), and 0.87 (3 H, d, *J* 7.0 Hz, CH_XMe); $\delta_C(CDCl_3)$ 137.09, 129.13, 128.90, 79.35, 66.59, 63.05, 34.71, 30.38, 29.21, 26.20, 21.96, 21.69 and 18.45 (Found: M$^+$ − $C_4H_9O_2$, 191.0883. $C_{12}H_{15}S$ requires M − $C_4H_9O_2$, 191.0894); *m*/*z* 191 [57%, M − CH(OH)CH(Me)CH_2OH], 110 (67, PhSH) and 82 (100).

(2RS,3RS)-2-*Methyl*-1-[1-(*phenylthio*)*cyclohexyl*]*propane*-1,3-*diol*, syn-**18b**.—In the same way, the esster *syn*-**9b** (X = OMe) (1.15 g, 3.7 mmol) and $LiAlH_4$ (0.19 g, 4.9 mmol) gave, after recrystallisation from diethyl ether–hexane, the *diol* **18b** (0.864 g, 83%) as needles, m.p. 79.5–80 °C; R_f[methanol–CH_2Cl_2 (1:20)] 0.27; ν_{max}(Nujol)/cm^{-1} 3400br (OH) and 1580 (SPh); $\delta_H(CDCl_3)$ 7.51–7.25 (5 H, m, SPh), 3.60 (1 H, dd, J_{AB} 10.4, J_{AX} 4.6 Hz, CH_AH_BOH), 3.55 (1 H, d, *J* 5.4 Hz, C*H*OH), 3.53 (1 H, dd, J_{BA} 10.4, J_{BX} 5.4 Hz, CH_AH_BOH), 2.1—1.19 (11 H, m, C_6H_{10} and CH_XMe) and 1.05 (3 H, d, *J* 7.0 Hz, CH_XMe); $\delta_C(CDCl_3)$ 137.09, 130.49, 128.96, 128.81, 75.33, 69.33, 62.28, 35.26, 31.11, 30.94, 26.10, 22.08, 21.89 and 11.79 (Found: M$^+$ − $C_4H_9O_2$, 191.0890. $C_{12}H_{15}S$ requires M − $C_4H_9O_2$, 191.0894); *m*/*z* 191 (45%, M − $C_4H_9O_2$, 191.0890. 191.0894); *m*/*z* 191 (45%, M − $C_4H_9O_2$), 171 (20, M − SPh), 125 (26), 110 (74, PhSH) and 81 (100, C_6H_9).

(1RS,2RS)-2-*Methyl*-1-[1-(*phenylthio*)*cyclopentyl*]*propane*-1,3-*diol* anti-**18a**.—In the same way, the ester *anti*-**10a** (694 mg) gave a pale yellow solid (473 mg). Crystallisation from hexane–diethyl ether gave the *alcohol* **18a** (320 mg, 85%) as needles, m.p. 66—68 °C (Found: C, 67.4; H, 8.5. $C_{15}H_{22}O_2S$ requires C, 67.6; H, 8.3%); $R_f[CH_2Cl_2$–MeOH (95:5)] 0.39; ν_{max}(Nujol)/cm^{-1} 3400 (OH); $\delta_H(CDCl_3)$ 7.52–7.29 (5 H, m, Ph), 3.79–3.63 (2 H, ABX system, *J*/Hz 11.1, 3.5 and 6.4, CH_2OH), 3.49 (1 H, d, *J* 5.5 Hz, C*H*OH), 3.18–3.15 (1 H, br, OH), 2.09–1.55 (9 H, m, $[CH_2]_4$ and C*H*Me) and 0.90 (3 H, d, *J* 7.0 Hz, Me).

(1RS,2RS)-2-*Methyl*-1-[1-*methyl*-4-(*phenylthio*)*piperidin*-4-*yl*]*propane*-1,3-*diol*, anti-**18c**.—In the same way, the ester *anti*-**10c** (4.1 g, 10 mmol) and lithium aluminium hydride (0.78 g, 20.5 mmol) gave the *diol* **18c** (2.49 g, 85%), recrystallised from ethyl acetate as cubes, m.p. 133–135 °C; R_f[ethyl acetate–methanol–triethylamine (75:25:1)] 0.20; $\nu_{max}(CDCl_3)$/cm^{-1} 3420 (OH) and 1580 (SPh); $\delta_H(CDCl_3)$ 7.50–7.45 (2 H, m, Ph), 7.40–7.25 (3 H, m, Ph), 3.98 (1 H, br s, OH), 3.76 (1 H, dd, *J*/Hz 11.0 and 3.4, CH_AH_BOH), 3.62 (1 H, dd, *J*/Hz 11.1 and 6.1, CH_AH_BOH), 3.30 (1 H, d, *J* 4.6 Hz, C*H*OH), 2.74–2.61 (3 H, m, NCH_2^{eq} and NCH^{ax}), 2.53 (1 H, dt, *J*/Hz 2.8 and 11.6, NCH^{ax}), 2.32 (3 H, s, NMe), 2.16–2.02 (2 H, m, NCH_2CH_2^{ax}), 1.87–1.75 (1 H, m, C*H*Me), 1.61 (1 H, dd, *J*/Hz 14.5 and 2.6, NCH_2CH*H*^{eq}), 1.33 (1 H, dd, *J*/Hz 14.2 and 2.6, NCH_2CH*H*^{eq}) and 0.92 (3 H, d, *J* 7.1 Hz, CH*Me*); $\delta_C(CDCl_3)$ 137.33, 129.42, 129.30, 129.01, 79.33, 66.37, 59.78, 51.46, 51.14, 46.25, 34.49, 29.65, 29.09 and 18.45 (Found: M$^+$ − C_3H_7O, 236.1117. $C_{13}H_{18}NOS$ requires M − C_3H_7O, 236.1110); *m*/*z* 236 (1%, M$^+$ − C_3H_7O), 186 (100, M − PhS), and 96 (50, $C_6H_{10}N$) (Found: C, 64.7; H, 8.65; N, 4.7; S, 10.7. $C_{16}H_{25}NO_2S$ requires C, 65.0; H, 8.55; N, 4.7; S, 10.85%).

* Revealed after D_2O shake.

(3RS,4SR)-3-*Methyl*-4-*phenylthio*-1-*oxaspiro*[4.5]*decane*, anti-**20b**.—The diol *anti*-**18b** (71 mg, 0.25 mmol) was refluxed in dry benzene (2 cm^3) and TsOH (5 mg, 0.3 mmol) was added. After 5 min, the solution was cooled in ice, passed through a short silica column, eluting with CH_2Cl_2, and the eluate was evaporated under reduced pressure to give the *title tetrahydrofuran* **20b** (65 mg, 98%) as an oil, $R_f(CH_2Cl_2)$ 0.4; ν_{max}(film)/cm^{-1} 2950–2850 (C–H); $\delta_H(CDCl_3)$ 7.47–7.18 (5 H, m, SPh), 3.97 (1 H, t, *J* 8.3 Hz, CH_AH_BOR), 3.35 (1 H, t, *J* 8.3 Hz, CH_AH_BOR), 2.79 (1 H, d, *J* 10.4 Hz, C*H*SPh), 2.29 (1 H, sym m, C*H*Me), 1.65–1.41 (10 H, m, C_6H_{10}) and 1.09 (3 H, d, *J* 6.6 Hz, CH*Me*); $\delta_C(CDCl_3)$ 136.39, 131.68, 128.91, 126.84, 84.01, 71.12, 64.99, 40.78, 36.57, 31.60, 25.66, 23.00, 21.87 and 16.70 (Found: M^+, 262.1373. $C_{16}H_{22}OS$ requires M, 262.1386); *m/z* 262 (10%, M^+), 164 (100, M − $C_6H_{10}O$), 149 (28), 110 (64, PhSH) and 55 (73).

(3RS,4RS)-3-*Methyl*-4-*phenylthio*-1-*oxaspiro*[4.5]*decane*, syn-**20b**.—In the same way, the diol *syn*-**18b** (54 mg, 0.20 mmol) gave the (3RS,4RS)-*tetrahydrofuran* **20b** (47 mg, 92%) as an oil, $R_f(CH_2Cl_2)$ 0.55; ν_{max}(film)/cm^{-1} 1530 (SPh); $\delta_H(CDCl_3)$ 7.38–7.13 (5 H, m, Ph), 4.0 (1 H, dd, J_{AX} 7.1, J_{AB} 8.8 Hz, CH_AH_BOR), 3.51 (1 H, dd, J_{BX} 6.2, J_{BA} 8.8 Hz, CH_AH_BOR), 3.44 (1 H, d, *J* 8.2 Hz, C*H*SPh), 2.67 (1 H, sym m, CH_XMe), 1.76–1.15 (10 H, m, C_6H_{10}) and 1.10 (3 H, d, *J* 7.2 Hz, CH_XMe); $\delta_C(CDCl_3)$ 137.41, 129.69, 128.94, 126.00, 83.87, 71.78, 60.67, 37.18, 37.11, 32.76, 25.44, 23.31, 22.32 and 15.63 (Found: M^+, 262.1400. $C_{16}H_{22}OS$ requires M, 262.1391); *m/z* 262 (6%, M^+), 164 (58, M − $C_6H_{10}O$), 149 (15), 110 (40, PtSH) and 55 (100).

(3RS,4SR)-3-*Methyl*-4-*phenylthio*-1-*oxaspiro*[4,4]*nonane*, anti-**20a**.—In the same way, the alcohol *anti*-**17a** (55 mg) gave the *tetrahydrofuran* **20a** (49 mg, 96%) as an oil, R_f[hexane–diethyl ether (2:1)] 0.50; $\delta_H(CDCl_2)$ 7.50–7.20 (5 H, m, Ph), 3.95 (1 H, dd, *J*/Hz 8.4 and 8.4, CH_AH_BO, *trans* to Me), 3.36 (1 H, dd, *J*/Hz 8.4 and 8.4, CH_AH_B, *cis* to Me), 3.09 (1 H, d, *J* 10.1 Hz, C*H*SPh), 2.32–2.19 (1 H, m, C*H*Me), 1.95–1.82 (8 H, m, $[CH_2]_4$) and 1.11 (3 H, d, *J* 6.6 Hz, Me); NOE irradiation at δ 3.95 (enhancement at δ 3.36 and 2.25), 3.36 (3.95, 2.25 and 1.11), 3.09 (7.50–7.20), and 2.25 (3.36 and 1.11) (Found: M^+, 248.1230. $C_{15}H_{20}OS$ requires M, 248.1235); *m/z* 248 (32%, M^+), 164 (100, M − C_5H_8O) and 110 (50, PhSH).

(3RS,4SR)-3,8-*Dimethyl*-4-*phenylthio*-1-*aza*-1-*oxaspiro*[4,5]-*decane*, anti-**20c**.—TsOH (2 g, 10 mmol) was added to a solution of the diol *anti*-**18c** (1.0 g, 3.4 mmol) in benzene (5 cm^3) in a foil-wrapped flask under argon. The solution was refluxed for 20 min, CH_2Cl_2 (30 cm^3) and water (20 cm^3) were added, the solution was basified (NaOH), and the organic layer was separated. The aqueous layer was extracted with CH_2Cl_2 (3 × 40 ml). The combined organic phases were dried (Na_2SO_4), evaporated, and purified by column chromatography on silica gel (95 g), eluting with CH_2Cl_2–methanol–triethylamine (92:7:1) to give the *tetrahydrofuran* **20c** (0.8 g, 85%) as an oil, R_f[CH_2Cl_2–methanol–triethylamine (89:10:1)] 0.37; $\nu_{max}(CHCl_3)$/cm^{-1} 1580 (phS); $\delta_H(CDCl_3)$ 7.46–7.41 (2 H, m, Ph), 7.29–7.16 (3 H, m, Ph), 3.98 (1 H, t, *J* 8.3 Hz, CH_AH_BO, *trans* to Me), 3.36 (1 H, t, *J* 8.7 Hz, CH_AH_BO, *cis* to Me), 2.82 (1 H, d, *J* 10.6 Hz, C*H*SPh), 2.73–2.59 (2 H, m, NCH_2), 2.30–2.16 (3 H, m, NCH_2 and C*H*Me), 2.25 (3 H, s, NMe), 1.99 (1 H, dt, *J*/Hz 4.3 and 13.0, NCH_2CH^{ax}), 1.79 (1 H, dt, *J*/Hz: 4.7 and 13.0, NCH_2CH^{ax}), 1.53 (1 H, ddd, *J*/Hz 2.7, 5.4 and 13.3, NCH_2CH^{eq}), 1.40 (1 H, ddd, *J*/Hz 2.7, 5.4 and 13.3, NCH_2CH^{eq}) and 1.14 (3 H, d, *J* 6.6 Hz, CH*Me*); $\delta_C(CDCl_3)$ 135.93, 131.76, 128.97, 126.96, 81.48, 71.00, 64.11, 52.30, 51.43, 46.16, 40.31, 35.71, 31.31, 29.66 and 16.39 (Found: M^+, 277.1419. $C_{16}H_{23}NOS$ requires M, 277.1500); *m/z* 277 (18%, M^+), 168 (88, M^+ − PhS) and 70 (100, C_4H_8N).

(1RS,2RS)-3-(t-*Butyldiphenylsiloxy*)-2-*methyl*-1-[1-(*phenylthio*)*cyclohexyl*]*propan*-1-*ol*, anti-**21b** (R = Bu^tPh_2Si).—t-Butyldiphenylsilyl chloride (837 mg, 3.04 mmol) was added to a solution of the diol *anti*-**18b** (775 mg, 2.77 mmol) and imidazole (414 mg, 6.09 mmol) in dry dimethylformamide (15 cm^3) under nitrogen at room temperature. After 24 h, DMF was evaporated under reduced pressure, the residue was taken up in CH_2Cl_2 (50 cm^3), and the solution was washed with water (100 cm^3). The aqueous layer was extracted with CH_2Cl_2 (2 × 30 cm^3) and the combined organic phases were dried ($MgSO_4$), evaporated under reduced pressure, and purified by column chromatography on silica gel, eluting with CH_2Cl_2 to give the *silyl ether* (1.42 g, 99%) as prisms, m.p. 90–91 °C (from hexane) (Found: C, 73.9; H, 8.0; S, 6.4. $C_{32}H_{42}O_2SSi$ requires C, 74.1; H, 8.1; S, 6.2%); $R_f(CH_2Cl_2)$ 0.52; $\nu_{max.}$(Nujol)/cm^{-1} 3450 (OH); $\delta_H(CDCl_3)$ 7.76–7.25 (15 H, m, Ph), 3.92 (1 H, dd, J_{AB} 10.2, J_{AX} 5.4 Hz, CH_AH_BOSi), 3.77 (1 H, dd, J_{BA} 10.2, J_{BX} 4.1 Hz, CH_AH_BOSi), 3.34 (1 H, d, *J* 3.3 Hz, C*H*OH), 2.0 (1 H, sym m, CH_XMe), 1.87–1.16 (10 H, m, C_6H_{10}), 1.11 (3 H, d, *J* 7.1 Hz, CH_XMe) and 1.05 (9 H, s, Bu^t); $\delta_C(CDCl_3)$ 136.92, 135.61, 135.57, 133.26, 131.10, 129.62, 129.60, 128.48, 127.58, 79.34, 67.11, 61.39, 35.50, 30.72, 26.87, 25.85, 21.91, 28.82, 12.12 and 18.91 [Found: M^+ − (PhSH + Bu^t), 351.1778. $C_{22}H_{22}O_2Si$ requires M − $C_{10}H_{15}S$, 351.1774]; *m/z* 351 [25%, M − (PhSH + Bu^t)], 199 (100, Ph_2SiOH), 135 (52) and 110 (32, PhSH).

(1RS,2SR)-3-(*t-Butyldiphenylsiloxy*)-2-*methyl*-1-[1-(*phenylthio*)*cyclohexyl*]*propan*-1-*ol*, syn-**21b**.—In the same way, the (1*RS*,2*SR*)-diol *syn*-**18b** (0.8 g, 2.86 mmol) gave the (1RS,2SR)-*silyl ether* **21b** (1.39 g, 94%) as an oil, $R_f(CH_2Cl_2)$ 0.71; ν_{max}(film)/cm^{-1} 3450 (OH) and 1580 (SPh); $\delta_H(CDCl_3)$ 7.63–7.25 (15 H, m, Ph), 3.68 (1 H, br s, OH), 3.48 (1 H, dd, J_{AB} 10.8, J_{AX} 7.2 Hz, CH_AH_BOSi), 3.51 (1 H, dd, J_{BA} 10.8, J_{BX} 5.2 Hz, CH_AH_BOSi), 3.11 (1 H, d, *J* 2.4 Hz, C*H*OH), 2.21–1.1 (11 H, m, C_6H_{10} and C*H*Me), 1.00 (3 H, d, *J* 6.9 Hz, CH_XMe) and 0.94 (9 H, s, Bu^t); $\delta_C(CDCl_3)$ 137.08, 135.60, 135.50, 133.65, 133.47, 130.58, 129.59, 129.55, 128.76, 127.61, 73.38, 69.10, 62.48, 35.52, 31.08, 30.82, 26.81, 26.13, 22.07, 21.97, 19.11 and 11.99 [Found: M^+ − (Bu^t + PhSH), 351.1784. $C_{22}H_{27}O_2Si$ requires M − $C_{10}H_{15}S$, 351.1780]; *m/z* 351 [10%, M − (Bu^t + PhSH)], 199 (100, Ph_2SiOH), 125 (64) and 110 (48, PhSH).

(1RS,2RS)-3-(*t-Butyldiphenylsiloxy*)-2-*methyl*-1-[1-(*phenylthio*)*cyclopentyl*]*propan*-1-*ol*, anti-**21a**.—In the same way, the diol *anti*-**18a** (210 mg) gave the *silyl ether* (332 mg, 83%) as an oil, R_f[CH_2Cl_2–hexane (1:1)] 0.45; ν_{max}(film)/cm^{-1} 3475 (OH); $\delta_H(CDCl_3)$ 7.69–7.25 (15 H, m, Ph), 3.97 (1 H, dd, *J*/Hz 4.0 and 10.3, CH_AH_BOSi), 3.72 (1 H, dd, *J*/Hz 4.6 and 10.3, CH_AH_BOSi), 3.57 (1 H, t, *J* 2 Hz, C*H*OH), 2.58–2.42 (1 H, m, C*H*Me), 1.87–1.55 (8 H, m, $[CH_2]_4$), 1.09 (3 H, d, *J* 7.2 Hz, Me) and 1.06 (9 H, s, Bu^t) (Found: M − Bu^t, 447.1801. $C_{27}H_{31}OSSi$ requires *m/z*, 447.1814); *m/z* 447 (5%, M − Bu^t), 227 [100, $C_5H_6CH(OH)CHMeCH_2OSiPh_2$] and 249 (38, M − Ph_2Bu^tSiO).

(1RS,2RS)-3-(*t-Butyldiphenylsiloxy*)-2-*methyl*-1-(1-*methyl*-4-*phenylthiopiperidin*-4-*yl*)*propan*-1-*ol*, anti-**21c** (R = $SiPh_2Bu^t$).—In the same way, the diol *anti*-**18c** gave the *silyl ether* (74 mg, 82%), recrystallised from CH_2Cl_2–light petroleum (b.p. 60–80 °C), as needles, m.p. 91–93 °C; R_f[ethyl acetate–methanol–triethylamine (74:25:1)] 0.31; $\nu_{max}(CDCl_3)$/cm^{-1} 3430 (OH) and 1580 (SPh); $\delta_H(CDCl_3)$ 7.70–7.65 (4 H, m, Ph), 7.54–7.20 (2 H, m, Ph), 7.43–7.25 (9 H, m, Ph), 4.02 (1 H, d, *J* 4.7 Hz, OH), 3.96 (1 H, dd, *J*/Hz 10.3 and 4.5, CH_AH_BOSi), 3.44 (1 H, t, *J* 4.1 Hz, C*H*OH), 2.62–2.57 (4 H, m, NCH_2), 2.38–2.35 (1 H, m, NCH_2CH^{ax}), 2.32 (3 H, s, NMe), 2.18–1.95 (2 H, m, C*H*Me and NCH_2CH^{ax}), 1.57–1.48 (2 H, m, $NCH_2CH_2^{eq}$), 1.10 (3 H, d, *J* 7.1 Hz, CH*Me*) and 1.05 (9 H, s, CMe_3); $\delta_C(CDCl_3)$ 137.20, 135.72,

135.66, 132.92, 132.87, 130.73, 129.77, 128.70, 127.71, 80.04, 67.48, 58.04, 51.49, 51.36, 46.27, 35.16, 30.62, 30.43, 26.86, 19.16 and 18.77 (Found: $M^+ - C_3H_9$, 476.2103. $C_{28}H_{34}NO_2SSi$ requires $M - C_4H_9$, 476.2079); *m/z* 476 (14%, $M^+ - C_4H_9$), 424 (100, $M^+ - PhS$) and 366 [33, $M^+ - (PhSH + C_4H_9)$] (Found: C, 71.7; H, 8.25; N, 2.7; S, 6.1. $C_{32}H_{43}NO_2SSi$ requires C, 72.0; H, 8.1; N, 2.6; S, 6.0%).

(2RS,3RS)-3-*Hydroxy*-2-*methyl*-3-[1′-*methyl*-4′-(*phenylthio*)-*piperidin*-4′-*yl*]*propyl Benzoate*, anti-**21c**.—A solution of the diol *anti*-**18c** (30 mg, 0.1 mmol) and benzoic anhydride (50 mg, 0.22 mmol) in CH_2Cl_2 (1.0 cm^3) was stirred at room temperature under argon for four days. Water (10 cm^3) and CH_2Cl_2 (15 cm^3) were added, and the solution was neutralised with NaOH (3 cm^3; 0.1 mol dm^{-3}) and extracted with CH_2Cl_2 (3 × 20 cm^3). The combined extracts were dried (Na_2SO_4), evaporated, and purified by column chromatography on silica gel (5 g), eluting with CH_2Cl_2–methanol–triethylamine (90:9:1) to give the *ester* **21c** (39 mg, 96%) as an oil, R_f[CH_2Cl_2–methanol–triethylamine (87:12:1)] 0.39, $\nu_{max}(CHCl_2)/cm^{-1}$ 3300 (OH), 1700 (C=O), 1600 (Ph) and 1580 (Ph); $\delta_H(CDCl_3)$ 8.04–8.00 (2 H, m, Ph), 7.55–7.29 (8 H, m, Ph), 4.63 (1 H, dd, *J*/Hz 11.1 and 4.0, CH_AH_BO), 4.29 (1 H, dd, *J*/Hz 11.1 and 7.9, CH_AH_BO), 3.37 (1 H, d, *J* 3.6 Hz, C*H*OH), 2.87–2.78 (4 H, m, NCH_2^{eq} and NCH_2^{ax}), 2.47 (3 H, s, NMe), 2.39–2.32 (1 H, m, C*H*Me), 2.24–2.10 (1 H, m, NCH^{ax}), 1.96–1.82 (1 H, m, NCH^{ax}), 1.75 (1 H, dd, *J*/Hz 14.8 and 2.4, NCH_2CH^{eq}), 1.50 (1 H, dd, *J*/Hz 14.5 and 2.4, NCH_2CH^{eq}) and 1.14 (3 H, d, *J* 6.9 Hz, CH*Me*); $\delta_C(CDCl_3)$ 166.60, 137.21, 132.76, 130.46, 129.29, 129.03, 128.28, 77.89, 67.55, 59.32, 51.34, 51.13, 45.90, 33.25, 29.77, 29.58 and 19.06 (Found: $M^+ - PhS$, 290.1735. $C_{17}H_{24}NO_3$ requires $M - C_6H_5S$, 290.1757); *m/z* 290 (24%, $M^+ - PhS$), 168 (89, M − PhS − $PhCO_2H$) and 105 (100, PhCO).

(1′RS,2′SR)-1-[3′-(*t-Butyldiphenylsiloxy*)-2′-*methyl*-1′-(*phenylthio*)*propyl*]*cyclohexene*, syn-**22b**.—The hydroxy sulphide *anti*-(**21b**) (628 mg, 1.21 mmol) and TsOH (20 mg, 0.10 mmol) were refluxed in dry benzene for four min. After cooling, the solution was passed through a short silica column, eluting with CH_2Cl_2, and the solvents were evaporated off under reduced pressure to give the *allyl sulphide* syn-**22b** (605 mg, 98%) as needles, m.p. 85.5–86.5 °C (from diethyl ether–methanol); $R_f(CH_2Cl_2)$ 0.85; ν_{max}(Nujol) 1660 cm^{-1} (C=C); $\delta_H(CDCl_3)$ 7.69–7.19 (15 H, m, Ph), 5.29 (1 H, br s, CH=C), 3.68 (1 H, d, *J* 9.5 Hz, C*H*SPh), 3.62 (1 H, dd, J_{AB} 9.90, J_{AX} 4.3 Hz, CH_AH_BOSi), 3.50 (1 H, d, J_{BA} 9.9, J_{BX} 5.7 Hz, CH_AH_BOSi), 2.20–1.37 (9 H, m), 1.28 (3 H, d, *J* 6.7 Hz, CH_XMe) and 1.06 (9 H, s, Bu^t); $\delta_C(CDCl_3)$ 136.34, 135.62, 135.57, 135.19, 133.86, 133.68, 132.71, 129.49, 128.29, 127.57, 126.47, 125.82, 66.66, 60.87, 37.76, 26.87, 25.16, 24.45, 22.71, 22.43, 19.29 and 15.59 (Found: $M^+ - Bu^t$, 443.1892. $C_{28}H_{31}OSSi$ requires $M - C_4H_9$, 443.1865); *m/z* 443 (10%, M − Bu^t), 333 (48, M − Bu^t − PhSH) and 199 (100, Ph_2SiOH).

(1′RS,2′RS)-1-[3′-(*t-Butyldiphenylsiloxy*)-2′-*methyl*-1′-(*phenylthio*)*propyl*]*cyclohexene*, anti-**22b**.—In the same way, the hydroxy sulphide *syn*-**21b** (790 mg, 1.53 mmol) gave the *allyl sulphide*-**22b** (766 mg, 98%) as an oil, $R_f(CH_2Cl_2)$ 0.83; ν_{max}(film)cm^{-1} 1660 (C=C); $\delta_H(CDCl_3)$ 7.27–7.17 (15 H, m, Ph), 5.22 (1 H, m, CH=C), 3.90 (1 H, dd, J_{AB} 9.9, J_{AX} 5.1 Hz, CH_AH_BOSi), 3.80 (1 H, dd, J_{BA} 9.9, J_{BX} 3.6 Hz, CH_AH_BOSi), 3.67 (1 H, d, *J* 9.9 Hz, C*H*SPh), 2.35–1.45 (9 H, m, C_6H_8 and CH_XMe), 1.06 (9 H, s, Bu^t) and 0.99 (3 H, d, *J* 6.8 Hz, CH_XMe); $\delta_C(CDCl_3)$ 135.70, 135.05, 133.94, 132.88, 129.52, 129.48, 128.30, 127.58, 126.55, 126.10, 66.52, 59.86, 37.80, 26.95, 25.23, 24.26, 22.55, 19.42 and 15.95 (Found: $M^+ - C_{16}H_{18}$, 290.1181. $C_{16}H_{22}OSSi$ requires $M - C_{16}H_{18}$, 290.1161); *m/z* 290 (28%, $M - C_{16}H_{18}$), 181 (73), 149 (74), 121 (100) and 93 (85).

(1′RS,2′SR)-1-[3′-(*t-Butyldiphenylsiloxy*)-2′-*methyl*-1′-(*phenylthio*)*propyl*]*cyclopentene*, syn-**22a**.—In the same way, the alcohol *anti*-**21a** (77 mg) gave the *allyl sulphide* syn-**22a** (75 mg, 100%) as an oil, R_f[CH_2Cl_2–hexane (1:1)] 0.71; ν_{max}(film)/cm^{-1} 3055 and 3045 (C=C); $\delta_H(CDCl_3)$ 7.64–7.18 (15 H, m, Ph), 5.33 (5 H, br s, CH=C), 4.03 (1 H, d, *J* 7.8 Hz, C*H*SPh), 3.65 (1 H, dd, *J*/Hz 5.4 and 9.9, CH_AH_BOSi), 3.48 (1 H, dd, *J*/Hz 5.6 and 9.9, CH_AH_BOSi), 2.44–2.31 (1 H, m, C*H*Me), 2.15–1.58 (6 H, m, $[CH_2]_3$), 1.15 (3 H, d, *J* 6.9 Hz, Me) and 1.02 (9 H, s, Bu^t) (Found: M − Bu^t, 429.1722. $C_{27}H_{29}OSSi$ requires *m/z* 429.1708); *m/z* 429 (1%, M^+) and 199 (100, Ph_2SiOH).

(2RS,3SR)-2-*Methyl*-3-(1-*methylpiperid*-1,2,3,6-*tetrahydropyridin*-4-*yl*)-3-*phenylthiopropyl Benzoate*, syn-**22c**.—The ester **21c** (17 mg, 0.043 mmol) and TsOH (24 mg, 0.19 mmol) were refluxed in benzene (1.0 cm^3) under argon for 15 min. Water (10 cm^3) and CH_2Cl_2 (20 cm^3) were added, and the solution was basified with NaOH (6 cm^3; 0.1 mol dm^{-3}) and extracted with CH_2Cl_2 (3 × 20 cm^3). The combined extracts were dried (Na_2SO_4), evaporated, and purified by column chromatography on silica gel (3 g), elution with CH_2Cl_2–methanol–triethylamine (94:5:1), to give the *ester* syn-**22c** (14 mg, 86%) as an oil, R_f[CH_2Cl_2–methanol–triethylamine (94:5:1)] 0.36; $\nu_{max}(CDCl_3)/cm^{-1}$ 1705 (C=O), 1600 (Ph) and 1580 (Ph); $\delta_H(CDCl_3)$ 8.01–7.97 (2 H, m, Ph), 7.54–7.18 (8 H, m, Ph), 5.32 (1 H, br s, CH=C), 4.38 (1 H, dd, *J*/Hz 11.0 and 4.8, CH_AH_BO), 4.14 (1 H, dd, *J*/Hz 11.0 and 6.8, CH_AH_BO), 3.59 (1 H, d, *J* 8.8 Hz, C*H*SPh), 2.96–2.86 (2 H, m, NCH_2C=C), 2.70–2.56 (2 H, m, NCH_2CH_2), 2.54–2.42 (1 H, m, NCH_2CH), 2.38–2.12 (2 H, m, NCH_2CH and C*H*Me), 2.27 (3 H, s, NMe) and 1.25 (3 H, d, *J* 6.7 Hz, CH*Me*); $\delta_C(CDCl_3)$ 166.33, 135.33, 133.35, 132.90, 130.23, 129.50, 128.61, 128.36, 127.07, 123.62, 67.81, 60.16, 54.14, 51.79, 45.35, 34.92, 25.40 and 15.52 (Found: $M^+ - PhS$, 272.1630. $C_{17}H_{22}NO_2$ requires $M - C_6H_5S$, 272.1651); *m/z* 272 (100%, $M^+ - PhS$), 150 (91, M − PhS − $PhCO_2H$) and 105 (82, PhCO).

[1RS,2′SR]-(E)-2-[3′-(*t-Butyldiphenylsiloxy*)-2′-*methylpropylidene*]*cyclohexanol*, (E)-syn-**23b**.—A solution of *m*-chloroperoxybenzoic acid (MCPBA) (151 mg, 0.66 mmol) in diethyl ether (5 cm^3) was added to a solution of the allyl sulphide (*E*)-*syn*-**22b** (300 mg, 0.6 mmol) in dry diethyl ether (10 cm^3) at 0 °C under nitrogen. After 0.5 h, the mixture was diluted with diethyl ether (100 cm^3) and washed successively with aq. sodium thiosulphate (2 × 15 cm^3), aq. sodium hydrogen carbonate (3 × 15 cm^3), and brine (15 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. Purification by column chromatography on silica gel, eluting with ethyl acetate–CH_2Cl_2 (1:20) gave a 3:1 mixture of allyl sulphoxides (272 mg, 88%). A solution of sodium benzenethiolate [from sodium hydroxide (130 mg, 3.3 mmol) and thiophenol (230 mg, 2.1 mmol)] in methanol (12 cm^3) was added to the mixture of allyl sulphoxides and the resulting mixture was refluxed for 20 min, then cooled. Methanol was evaporated off under reduced pressure, sodium hydroxide (30 cm^3 of a 5% solution) was added, and the solution was extracted with diethyl ether (3 × 20 cm^3). The combined extracts were dried ($MgSO_4$), and evaporated under reduced pressure. Purification by column chromatography on silica gel, eluting with ethyl acetate–CH_2Cl_2 (1:50) gave the *allylic alcohol* **23b** as an oil (170 mg, 79%), R_f[ethyl acetate–CH_2Cl_2 (1:20)] 0.44; ν_{max}(film)/cm^{-1} 3350 (OH) and 1655 (C=C); $\delta_H(CDCl_3)$ 7.69–7.25 (10 H, m, Ph), 5.09 (1 H, d, *J* 9.3 Hz, CH=C), 4.05 (1 H, m, C*H*OH), 3.47 (2 H, m, CH_2OSi), 2.65 (1 H, sym m, C*H*Me), 2.34 (1 H, m, C*H*CH=C), 1.90–1.18 (7 H, m), 1.06 (9 H, s, Bu^t) and 1.01 (3 H, d, *J* 6.7 Hz, CH*Me*); $\delta_C(CDCl_3)$ 141.52, 135.64, 134.80, 134.09, 129.61, 129.50, 127.69, 127.55, 124.02, 73.61, 68.84, 36.09, 34.27,

27.41, 27.07, 26.91, 26.57, 26.40, 22.88, 19.29 and 17.77 (Found: $M^+ - Bu^t$, 351.1749. $C_{22}H_{27}O_2Si$ requires $M - C_4H_9$, 351.1774); *m/z* 351 (6%, M − Bu^t), 273 (15, M − Bu^t − PhH), 199 (100, Ph_2SiOH) and 125 (58).

(1RS,2′RS)-2-[3′-(*t-Butyldiphenylsiloxy*)-2′-*methylpropylidene*]*cyclohexanol*, (E)-anti-**23b**.—Oxidation and rearrangement of the allyl sulphide (*E*)-*anti*-**22b** (650 mg, 1.3 mmol) by the same method gave the intermediate allyl sulphoxide (0.595 g, 89%) and then the *allylic alcohol* (360 mg, 88%, 77% over the two steps) as an oil, $R_f(CH_2Cl_2)$ 0.3; ν_{max}(film)/cm^{-1} 3400 (OH); $\delta_H(CDCl_3)$ 7.70–7.25 (10 H, m, Ph), 5.10 (1 H, d, *J* 9.3 Hz, CH=C), 4.05 (1 H, m, C*H*OH), 3.48 (2 H, m, CH_2OSi), 2.65 (1 H, sym m, C*H*Me), 2.32 (1 H, m, C*H*CH=C), 1.87–1.41 (7 H, m, C_6H_7), 1.06 (9 H, s, Bu^t) and 1.01 (3 H, d, *J* 6.7 Hz, CH*Me*); $\delta_C(CDCl_3)$ 141.64, 135.65, 134.12, 134.07, 129.53, 127.58, 123.79, 73.62, 68.90, 36.25, 34.31, 27.40, 26.94, 26.50, 23.02, 19.33 and 17.76 (Found: $M^+ - Bu^t$, 351.1802. $C_{22}H_{22}O_2Si$ requires $M - C_4H_9$, 351.1780); *m/z* 351 (7%, M − Bu^t), 227 (24), 199 (100, Ph_2SiOH) and 135 (93).

(1RS,2RS)-3-(*t-Butyldiphenylsiloxy*)-1-(*cyclopent-1-enyl*)-2-*methylpropyl Phenyl Sulphoxide*.—A solution of MCPBA (80–85%; 27 mg) in dichloromethane (1 cm^3) was added to a solution of the sulphide *syn*-**22a** (50 mg) in dichloromethane (3 cm^3) in a foil-wrapped flask at −78 °C under nitrogen. The solution was stirred for 50 min, then brine (10 cm^3) and saturated aq. sodium thiosulphate (10 cm^3) were added and the mixture was allowed to warm to room temperature. The solution was extracted with dichloromethane (3 × 10 cm^3) and the combined extracts were dried ($MgSO_4$), then evaporated under reduced pressure to give the *sulphoxide* (56 mg, 100%) as a waxy solid, R_f[CH_2Cl_2–hexane (1:1)] 0.25; ν_{max}(Nujol)/cm^{-1} 3055 and 3045 (C=C); $\delta_H(CDCl_3)$ 8.09–7.29 (15 H, m, Ph), 5.53 and 5.16 (1 H, br t, CH=C, 1:3 ratio of diastereoisomers), 3.56 (2 H, dd, *J*/Hz 3.4 and 3.4, CH_2OSi), 3.14 (1 H, d, *J* 11.1 Hz, C*H*SOPh), 2.58–2.22 (1 H, m, C*H*Me), 2.28–1.87 (6 H, m, $[CH_2]_3$), 1.54 (3 H, d, *J* 6.6 Hz, Me), and 1.03 and 1.02 (9 H, s and s, Bu^t, 1:3 mixture of diastereoisomers) (Found: M − Bu^t, 445.1672. $C_{29}H_{29}O_2SSi$ requires *m/z*, 445.1658); *m/z* 445 (1%, M − Bu^t) and 197 (100, Ph_2SiOH).

(1RS,2′SR)-(E)-2-[3′-(*t-Butyldiphenylsiloxy*)-2′-*methylpropylylidene*]*cyclopentanol*, (E)-syn-**23a**.—A solution of the above sulphoxide (82 mg) in methanol (1 cm^3) was added to a mixture of sodium hydroxide (114 mg) and thiophenol (0.26 cm^3) in methanol (2 cm^3) in a foil-wrapped flask under nitrogen. The solution was heated under reflux for 10 min, the methanol was evaporated off under reduced pressure, and the residue taken into water (5 cm^3)–brine (20 cm^3) and extracted with diethyl ether (3 × 15 cm^3). The combined extracts were dried (Na_2SO_4), and evaporated under reduced pressure. The residue was purified by column chromatography on silica gel (10 g), eluting with CH_2Cl_2–propan-2-ol (98:2) to give the *alcohol* **23a** (30 mg, 66%) as an oil, R_f[CH_2Cl_2–Pr^{i}OH (98:2)] 0.24; ν_{max}(film)/cm^{-1} 3350 (OH), 3060 and 3050 (C=CH); $\delta_H(CDCl_3)$ 7.73–7.33 (10 H, m, Ph), 5.30 (1 H, ddd, *J*/Hz 9.5, 3.9 and 2.5, CH=C), 4.33 (1 H, br t, C*H*OH), 3.48 (2 H, d, *J* 6.6 Hz, CH_2OSi), 2.60–2.40 (1 H, m, C*H*Me), 2.40–2.05 (2 H, m, CH_2C=C), 1.92–1.72 (2 H, m, CH_2CHOH), 1.68–1.47 (3 H, m, $CH_2CH_2CH_2$ and OH), 1.03 (9 H, s, Bu^t) and 0.99 (3 H, d, *J* 6.8 Hz, Me) (Found: M − Bu^t, 337.1628. $C_{21}H_{25}O_2Si$ requires *m/z* 337.1624); *m/z* 337 (8%, M − Bu^t) and 199 (100, Ph_2SiOH).

(1RS,2′SR)-(E)-2-[3′-(*t-Butyldiphenylsiloxy*)-2′-*methylpropylidene*]*cyclohexyl* 3,5-*Dinitrobenzoate*, (E)-syn-**27**.—The allylic alcohol (*E*)-*syn*-**23b** (145 mg, 0.35 mmol), 3,5-dinitrobenzoyl chloride (90 mg, 0.38 mmol) and 4-(dimethylanilino)-pyridine (DMAP) (66 mg, 0.38 mmol) were stirred in dry CH_2Cl_2 (1 cm^3) under N_2. After 20 min, the mixture was purified by column chromatography on silica gel with CH_2Cl_2 as eluant to give the *ester* syn-**26** (189 mg, 89%) as an oil, $R_f(CH_2Cl_2)$ 0.66; ν_{max}(film)/cm^{-1} 1715 (C=O), 1620 (C=C), 1590, 1580, 1540 (NO_2) and 1350 (NO_2); $\delta_H(CDCl_3)$ 9.21–9.13 [3 H, m, $Ar(NO_2)_2$], 7.67–7.33 (10 H, m, Ph), 5.52 (1 H, m, CHOCO), 5.31 (1 H, d, *J* 8.8 Hz, CH=C), 3.48 (2 H, d, *J* 6.3 Hz, CH_2OSi), 2.67 (1 H, sym m, C*H*Me), 2.24–1.30 (8 H, m, C_6H_8), 1.03 (9 H, s, Bu^t) and 1.01 (3 H, d, *J* 6.3 Hz, CH*Me*) (Found: $M^+ - C_{10}H_{15}$, 467.1255. $C_{23}H_{23}N_2O_7Si$ requires $M - C_{10}H_{15}$, 467.1275); *m/z* 467 (4%, M − Bu^t − PhH), 393 (48), 333 (98, M − Bu^t − $ArCO_2H$) and 199 (100, Ph_2SiOH).

(1RS,2′RS)-(E)-2-[3′-(*t-Butyldiphenylsiloxy*)-2′-*methylpropylidene*]*cyclohexyl* 3,5-*Dinitrobenzoate*, (E)-anti-**27**.—In the same way the allylic alcohol *anti*-**22b** (268 mg, 0.66 mmol) gave the *ester* anti-**27**. (400 mg, 100%) as an oil, $R_f(CH_2Cl_2)$ 0.75; ν_{max}(film)/cm^{-1} 1715 (C=O), 1620 (C=C), 1590, 1580, 1560 (NO_2) and 1350 (NO_2); $\delta_H(CDCl_3)$ 9.18–9.07 [3 H, m, $Ar(NO_2)_2$], 7.63–7.25 (10 H, m, Ph), 5.57 (1 H, m, C*H*OCOR), 5.30 (1 H, d, *J* 9.2 Hz, CH=C), 3.49 (1 H, dd, J_{AB} 9.8, J_{AX} 6.8 Hz, CH_AH_BOSi), 3.44 (1 H, dd, J_{AB} 9.8, J_{BX} 6.6 Hz, CH_AH_BOSi), 2.67 (1 H, sym m, CH_XMe), 2.35–1.3 (8 H, m, C_6H_8), 0.97 (3 H, d, *J*, 6.7 Hz, CH_X*Me*) and 0.94 (9 H, s, Bu^t); $\delta_C(CDCl_3)$ 161.73, 148.65, 135.64, 135.55, 135.00, 133.81, 129.96, 129.54, 129.27, 127.58, 127.55, 122.65, 79.19, 68.37, 34.47, 32.91, 26.81, 26.75, 26.30, 22.30, 19.19 and 17.43 (Found: $M^+ - C_{10}H_{15}$, 467.1259. $C_{23}H_{23}N_2O_7Si$ requires $M - C_{10}H_{15}$, 467.1274); *m/z* (0.5%, M − PhH − Bu^t), 391 (5), 333 (7) and 199 (100, Ph_2SiOH).

(1RS,2′RS)-(E)-2-(3′-*Hydroxy*-2′-*methylpropylidene*)*cyclohexanol*, (E)-anti-**23b** (R = H).—Tetrabutylammonium fluoride (0.33 cm^3 of a 1 mol dm^{-3} solution in THF) was added to a solution of the silyl ether (*E*)-*anti*-**23b** (125 mg, 0.31 mmol) in THF (5 cm^3) and the mixture was stirred for two days. The reaction mixture was quenched with aq. ammonium chloride (20 cm^3), the organic layer was separated, and the aqueous layer was extracted with diethyl ether (2 × 5 cm^3). The combined organic phases were dried ($MgSO_4$), evaporated under reduced pressure, and purified by column chromatography on silica gel (10 g), eluting with methanol–CH_2Cl_2 (1:13) to give the *diol* (51 mg, 96%) as prisms, m.p. 80–82 °C (from diethyl ether–hexane); R_f[methanol–CH_2Cl_2 (1:13)] 0.14; ν_{max}(Nujol)/cm^{-1} 3350 (OH) and 1660 (C=C); $\delta_H(CDCl_3)$ 5.11 (1 H, dd, *J*/Hz 0.9 and 9.5, C=CH), 4.07 (1 H, m, C*H*OH), 3.49 (1 H, dd, J_{AB} 10.5, J_{AX} 5.6 Hz, CH_AH_BOH), 3.32 (1 H, dd, J_{BA} 10.5, J_{BX} 8.2 Hz, CH_AH_BOH), 2.65 (1 H, sym m, CH_XMe), 2.42 (1 H, m, RCH*H*C=C), 2.02 (1 H, m, RC*H*HC=C), 1.86–1.43 (6 H, m, $[CH_2]_3$) and 0.93 (3 H, d, *J* 6.7 Hz, CH_X*Me*) (Found: M^+, 170.1313. $C_{10}H_{18}O_2$ requires M, 170.1307); *m/z* 170 (8%, M^+), 152 (18, M − H_2O), 139 (32, M − CH_2OH), 122 (100), 111 (81) and 55 (76).

(1RS,2′RS)-(E)-2-(3′-*Hydroxy*-2′-*methylpropylidene*)*cyclopentanol*, (E)-syn-**23a** (R = H).—In the same way, alcohol (*E*)-*syn*-**23a** (20 mg) gave the *diol* (5.6 mg, 72%) as an oil, R_F[CH_2Cl_2–MeOH (95:5)] 0.17; ν_{max}(film)/cm^{-1} 3300 (OH); $\delta_H(CDCl_3)$ 5.31 (1 H, ddd, *J*/Hz 9.5, 4.1 and 2.5, CH=C), 4.40 (1 H, t, *J* 5.4 Hz, C*H*OH), 3.51 (1 H, dd, *J*/Hz 10.5 and 5.9, CH_AH_BOH), 3.39 (1 H, dd, *J*/Hz 10.5 and 7.8, CH_ACH_BOH), 2.49–2.39 (2 H, m, CH_2C=C), 2.28–2.20 (1 H, m, C*H*Me), 1.89–1.78 (2 H, m, CH_2CHOH), 1.66–1.52 (4 H, m, $CH_2CH_2CH_2$ and both OH) and 0.97 (3 H, d, *J* 6.7 Hz, Me) (Found: M^+, 156.1135. $C_9H_{16}O_2$ requires M, 156.1150); *m/z* 156 (3%, M^+), 125 (45, M − CH_2OH), 97 (100, C_6H_9O) and 55 (85, C_4H_6).

(2RS,3SR)-3-(*Cyclohex-1-enyl*)-2-*methyl*-3-*phenylthiopropan*-

1-ol, (E)-syn-**22b** (R = H).—$LiAlH_4$ (110 mg, 2.9 mmol) was added to a solution of the ester *anti*-**10b** (550 mg, 1.46 mmol) in dry diethyl ether (20 cm^3) at 0 °C and the mixture was stirred for two hours. Ethyl acetate (1 cm^3) was added and the reaction mixture was poured into aq. ammonium chloride (50 cm^3). Dil. hydrochloric acid (20 cm^3) was added, the organic layer was separated and the aqueous layer was extracted with diethyl ether (2 × 30 cm^3). The combined organic phases were washed successively with water (20 cm^3) and brine (20 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. Purification by column chromatography, eluting with MeOH–CH_2Cl_2 (1:200) gave the *alcohol* as an oil (359 mg, 94%), R_f(CH_2Cl_2) 0.16; ν_{max}(film)/cm^{-1} 3450 (OH) and 1580 (SPh); δ_H($CDCl_3$) 7.37–7.15 (5 H, m, SPh), 5.32 (1 H, br s, CH=C), 3.60 (1 H, dd, J_{AX} 4.8, J_{AB} 11.0 Hz, C$H_A$$H_B$OH), 3.47 (1 H, dd, J_{BX} 5.6, J_{BA} 11.0 Hz, CH$_A$$H_B$OH), 3.47 (1 H, d, *J* 9.4 Hz, C*H*SPh), 2.31–1.39 (9 H, m, C_6H_8 and C*H*Me) and 1.18 (3 H, d, *J* 6.7 Hz, CH*Me*) (Found: M^+, 262.1407. $C_{16}H_{22}OS$ requires M, 262.1391); *m/z* 262 (3%, M^+), 153 (16, M − SPh), 152 (16, M − PhSH), 135 (60), 121 (58), 110 (62, PhSH), 95 (82), 93 (82) and 79 (100).

(1RS,2′SR)-(E)-2-(*3′-Hydroxy-2-methylpropylidene*)*cyclohexanol*, (E)-syn-**23b** (R = H).—Sodium periodate (330 mg, 1.54 mmol) was added to a solution of the allyl sulphide (*E*)-*syn*-**22b** (359 mg, 1.37 mmol) in methanol (10 cm^3) and water (~20 drops) was added until a very faint precipitate persisted. After 24 h, methanol was removed under reduced pressure, brine (50 cm^3) was added, and the solution was extracted with ethyl acetate (3 × 20 cm^3). The combined extracts were dried, and the solvent was removed under reduced pressure to give the crude allyl sulphoxide (400 mg). A solution of sodium benzenethiolate [sodium hydroxide (260 mg, 6.5 mmol) and thiophenol (158 mg, 1.45 mmol)] in methanol (12 cm^3) was added and the mixture was refluxed for 0.5 h, then cooled, when aq. sodium hydroxide (5%; 50 cm^3) was added and the solution was extracted with diethyl ether (3 × 20 cm^3). The combined extracts were dried ($MgSO_4$) and evaporated under reduced pressure. Purification by column chromatography on silica gel (20 g), eluting with methanol–ethyl acetate (1:20) gave the *allylic alcohol* (177 mg, 76% over the two steps) as an oil, R_f[methanol–ethyl acetate (1:20)] 0.38; ν_{max}(film)/cm^{-1} 3300 (OH) and 1660 (C=C); δ_H($CDCl_3$) 5.15 (1 H, dd, *J*/Hz 9.3 and 1.1, C=CH), 4.08 (1 H, m, C*H*OH), 3.48 (1 H, dd, J_{AB} 10.4, J_{AX} 5.9 Hz, C$H_A$$H_B$OH), 3.34 (1 H, dd, J_{BA} 10.4, J_{BX} 8.1 Hz, CH$_A$$H_B$OH), 2.67 (1 H, sym m, C*H*Me), 2.48 (1 H, m, RC*H*HC=C), 2.05–1.35 (7 H, m) and 0.95 (3 H, 3 H, d, *J* 6.7 Hz, CH$_X$*Me*) (Found: M^+, 170.1305. $C_{10}H_{18}O_2$ requires M, 170.1307); *m/z* 170 (6%, M^+), 162 (12, M − H_2O), 139 (20, M − CH_2OH), 122 (42), 111 (68, M − C_3H_7O), 69 (76) and 55 (100).

3,8-*Dimethyl*-8-*aza*-1-*oxaspiro*[4.5]*dec*-3-*en*-2-*one* **25c**.—A solution of MCPBA (0.24 g, 1.1 mmol) in CH_2Cl_2 (8 cm^3) was added to a solution of the lactone hydrochloride *anti*-**12c** (0.332 g, 1.0 mmol) in CH_2Cl_2 (7 cm^3) under argon at −78 °C. After 20 min, the solution was allowed to warm to 0 °C and was stirred for one h. CH_2Cl_2 (100 cm^3), aq. sodium thiosulphate (60 cm^3), and aq. $NaHCO_3$ (50 cm^3) were added, the organic layer was removed, and the aqueous layer was extracted with CH_2Cl_2 (2 × 100 cm^3). The combined organic phases were dried (Na_2SO_4) and evaporated to give the sulphoxide **24c**, R_f[CH_2Cl_2–methanol–triethylamine (90:9:1)] 0.31; ν_{max}($CHCl_3$)/cm^{-1} 1760 (C=O) and 1048 (S=O), which was heated to 110 °C in dimethyl sulphoxide (DMSO) (1.0 cm^3) under argon. After 2 h, CH_2Cl_2 (30 cm^3) and water (30 cm^3) were added, the organic layer was removed and the aqueous layer was extracted with CH_2Cl_2 (2 × 30 cm^3). The combined organic phases were dried (Na_2SO_4), evaporated and the residue was purified by column chromatography on silica gel (25 g), eluting with CH_2Cl_2–ethanol–ammonia (120:8:1) to give the *butenolide* **25c** (92 mg, 50%) as needles, m.p. 117–119 °C; R_f[CH_2Cl_2–methanol–triethylamine (90:9:1)] 0.29; ν_{max}($CHCl_3$)/cm^{-1} 1735 (C=O) and 1655 (C=C); δ_H($CDCl_3$) 7.01 (1 H, d, *J* 1.6 Hz, HC=C), 3.00 (2 H, br d, *J* 10.9 Hz, NCH_2^{eq}), 2.73 (2 H, br t, *J* 11.8 Hz, NCH_2^{ax}), 2.51 (3 H, s, NMe), 2.29 (2 H, br t, *J* 11.1 Hz, $NCH_2CH_2^{ax}$), 1.91 (3 H, d, *J* 1.6 Hz, C=CMe) and 1.64 (2 H, br d, *J* 12.0 Hz, $NCH_2CH_2^{eq}$); δ_C($CDCl_3$) 173.04, 152.35, 129.43, 82.52, 51.53, 45.66, 33.93 and 10.55 (Found: M^+, 181.1099. $C_{10}H_{15}NO_2$ requires M, 181.1103); *m/z* 181 (60%, M^+), 180 (54, M − H), 70 (50, C_4H_8N) and 57 (100, C_3H_7N).

3,8-*Dimethyl*-8-*aza*-1-*oxaspiro*[4.5]*decane* **26c**.—Raney nickel (2 g of a 50% slurry in water) was added to a solution of the sulphide *anti*-**20c** (319 mg, 1.15 mmol) in ethanol (12 cm^3) and the mixture was heated under reflux under nitrogen for 45 min. The suspension was filtered to remove the catalyst, washed with ethanol, and evaporated to give an oil. The acid-washed catalyst was extracted with CH_2Cl_2 (2 × 25 cm^3), and the combined layers were dried (Na_2SO_4) and evaporated. Ethereal HCl (2 cm^3) was added to the combined oils, the solvent was evaporated off and the residue was triturated with diethyl ether to give the *hydrochloride salt of the amine* **26c** (44 mg, 19%) as needles, m.p. 157–159 °C; R_f[CH_2Cl_2–ethanol–ammonia (75:8:1)] 0.41; ν_{max}(Nujol)/cm^{-1} 3400 (OH) and 2750–2350 (NH^+); δ_H($CDCl_3$) 3.92 (1 H, t, *J* 8.0 Hz, C$H_A$$H_B$O), 3.36–3.28 (1 H, m, CHN) 3.31 (1 H, t, *J* 8.0 Hz, CH$_A$$H_B$O), 3.08 (2 H, br s, CH_2N), 2.73 (3 H, s, NMe), 2.52–2.25 (3 H, m, C*H*Me and NCH_2CH_2), 2.02 (1 H, dd, *J*/Hz 13.0 and 9.5, C$H_A$$H_B$CHMeCH$_2$O), 1.84–1.70 (2 H, m, NCH_2CH_2), 1.38 (1 H, dd, *J*/Hz 13.0 and 9.5, CH$_A$$H_B$CHMeCH$_2$O) and 1.05 (3 H, d, *J*/Hz 6.5, CH*Me*) (Found: M^+, 169.1470. $C_{10}H_{19}NO$ requires M, 169.1467); *m/z* 169 (23%, M^+), 110 (32, M^+ − C_3H_7O) and 96 (100, M^+ − C_4H_9O) (Found: C, 55.9; H, 10.15; N, 6.5. $C_{10}H_{19}NO$·HCl·0.5H_2O requires C, 55.9; H, 9.8; N, 6.5%).

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