Synthesis of Thiospiroacetals. X-Ray Crystal Structure Determinations for (7*RS*,11*RS*)-1,4,8-Trioxa-13-thiadispiro[4.1.5.3]pentadecan-11-ol and (4*RS*,6*SR*)-4-*p*-Nitrobenzoyloxy-1,7-dithiaspiro[5.5]undecane

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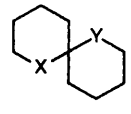
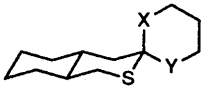
Deprotonation of 2-phenylthiotetrahydrothiopyran **10** and addition of the epoxide **14** gave the 2-alkyltetrahydrothiopyrans **16a, b**. Deprotection, followed by cyclisation using silver nitrate and triethylamine in aqueous acetonitrile, gave the monothiospiroacetals **18** and **19** (93%), ratio 67:33. The monothiospiroacetals **29** and **30** were similarly obtained from 2-phenylthiotetrahydrothiopyran **26**. The formation of dithiospiroacetals from 2-phenylthiotetrahydrothiopyrans was inefficient. However, the 2*H*-3,4-dihydrothiopyran **25** was alkylated using epoxides **14** and **56**, and the products converted into the dithiospiroacetals **48** and **50**, and **62** and **63**, respectively. The 2*H*-dihydrothiopyran **65** was similarly alkylated using the epoxide **14**, and the product taken through to provide the dithiospiroacetal **71**. In each case the major product was that expected on the basis of the anomeric effect. The structures of (7*RS*,11*RS*)-1,4,8-trioxa-13-thiadispiro[4.1.5.3]pentadecan-11-ol **18** and the *p*-nitrobenzoyloxydithiospiroacetal **49**, were established by X-ray crystallography.

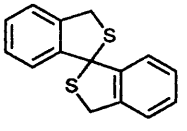
The [5.5]spiroacetal **1** is a substructure of many natural products some of which possess useful biological activity.[1] Many efficient procedures have been developed for the synthesis of these compounds because of their possible importance, for example as pharmaceuticals and agrochemicals.[2] In contrast, the chemistry of mono- and di-thiospiroacetals, *e.g.* **2** and **3**, has not been widely investigated, and few general methods are available for their synthesis.



1 X = Y = O
2 X = S, Y = O
3 X = Y = S



4 X = S, Y = CH_2
5 X = CH_2, Y = S



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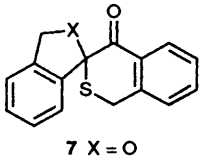
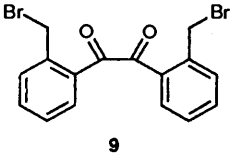


7 X = O
8 X = S



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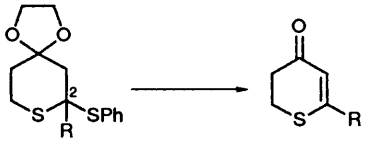
The parent compounds **2** and **3** and related tricyclic thiospiroacetals, *e.g.* **4** and **5**, were prepared by cyclisation of the appropriate mercapto ketones by Deslongchamps during his work on the anomeric effect.[3] The dithiospiroacetal **6** was prepared similarly,[4] and the polycyclic mono- and di-thiospiroacetals **7** and **8** were prepared by treatment of the dibromo diketone **9** with sodium hydrogen sulfide.[5] Dithiospiroacetals have been isolated in low yield from pyrolyses of dithiolactones,[6] from reactions between strained hydrocarbons and carbon disulfide,[7,8] and oxidised dithiospiroacetals from alkene–disulfene addition reactions.[9] We now describe syntheses of mono- and di-thiospiroacetals based on acyl carbanion chemistry.

Synthesis of Monothiospiroacetals.—Lithiated dithioacetals, *e.g.* 1,3-dithianes, are well known acyl carbanion equivalents.[10] The 2-phenylthiotetrahydrothiopyran **10** has been lithiated at C-2 and alkylated with a range of alkyl halides.[11] Hydrolysis of



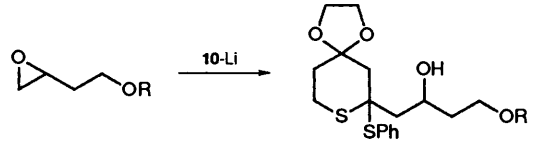
10 R = H
11 R = alkyl

12

Scheme 1

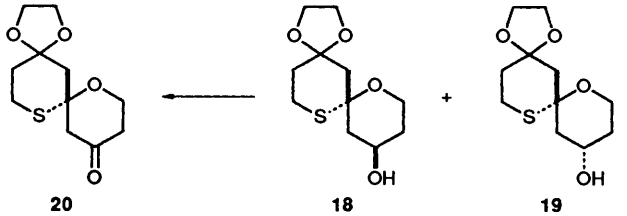
the products **11** gave the thiinones **12** (Scheme 1).[11] It was thought that this strategy could be used to provide access to thiospiroacetals if suitably functionalised substituents could be introduced at C-2 and induced to undergo intramolecular conjugate addition to the thiinones.

Alkylation of the 2-phenylthiotetrahydrothiopyran **10**[11,12] was carried out by deprotonation using butyllithium at −35 °C, followed by addition of the epoxide **13**[13] to give a mixture of the diastereoisomeric alcohols **15a, b** (Scheme 2) ratio 60:40, which were separated by flash chromatography. Attempts to remove the benzyl group by hydrogenolysis were unsuccessful,



13 R = Bn
14 R = $SiMe_2Bu^t$

15a,b R = Bn
16a,b R = $SiMe_2Bu^t$
17a,b R = H

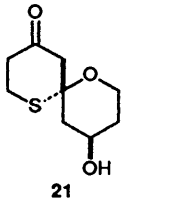


20 **18** **19**

Scheme 2

and so the analogous *tert*-butyldimethylsilyl ethers **16a**, **b** were prepared using the epoxide **14**,[14] and deprotected using tetrabutylammonium fluoride to give the diols **17a**, **b**.

It was hoped that acid catalysed hydrolysis of the alkylated tetrahydrothiopyrans **17a**, **b** would generate the corresponding 2-(hydroxyalkyl)thiinone which would cyclise to the monothiospiroacetal **21**. However, treatment of the major diol **17a** with aqueous hydrochloric acid in acetone (3.5 mol dm^{-3}) heated under reflux gave a complex mixture of products including the elimination product **22** and thioethers **23** and **24** derived from it.



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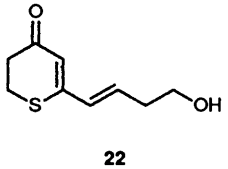

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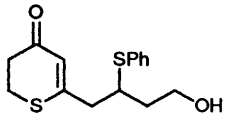

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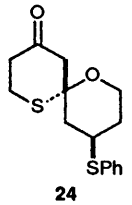

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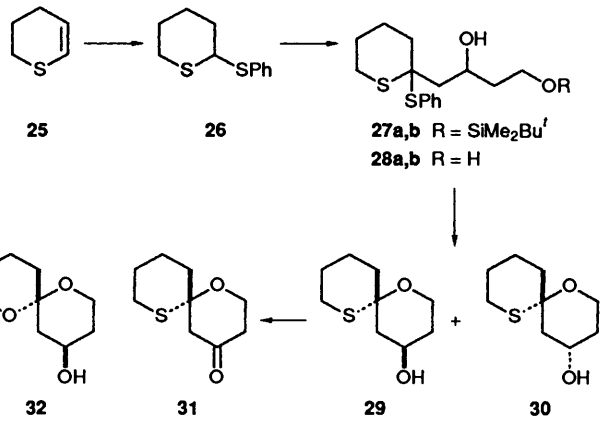
In order to promote cleavage of the dithioacetal whilst leaving the dioxolane ring intact, the induction of spirocyclisation by heavy metals salts was investigated. Mercuric oxide in the presence of boron trifluoride–diethyl ether in tetrahydrofuran (THF),[15] and silver perchlorate in wet benzene,[16] gave rise to complex mixtures of products. Mercuric chloride in THF gave a low yield of a single product, but silver tetrafluoroborate in aqueous acetonitrile[17] was more promising with a 67:33 mixture of the required monothiospiroacetals **18** and **19** being obtained in yields of up to 75%, together with variable amounts of the monothiospiroacetal **21** in which the dioxolane ring had been cleaved. Finally, the use of silver nitrate in aqueous acetonitrile containing triethylamine, to prevent the reaction mixture from becoming acidic, was found to give the best results, with the required monothiospiroacetals **18** and **19** being obtained in excellent yield (93%) from both **17a** and **b**.

Structures were assigned to these products on the basis of spectroscopic data, and were confirmed for compound **18** by an X-ray diffraction study *vide infra*. Oxidation of a mixture of the hydroxymonothiospiroacetals **18** and **19** using pyridinium dichromate–pyridinium trifluoroacetate gave the ketone **20**, which was reduced using sodium borohydride to give a mixture of the alcohols in which the axial epimer **19** predominated, **18**:**19** *ca.* 33:67. Attempts to equilibrate the isomers **18** and **19** individually using silver nitrate and triethylamine in aqueous acetonitrile were unsuccessful resulting in decomposition of starting material, and attempts to isomerize the minor isomer **19** to the major one **18** using toluene-*p*-sulfonic acid in methanol were thwarted by hydrolysis of the dioxolane and further decomposition.

2-Phenylthiotetrahydrothiopyran **26** is available from dihydrothiopyran **25** (Scheme 3) by treatment with thiophenol in benzene containing a catalytic amount of acid.[18] Deprotonation of **26** using butyllithium at −78 °C, followed by addition of epoxide **14** and slow warming to 0 °C (5 h), gave the alkylated tetrahydrothiopyrans **27a**, **b**. Deprotection of the less polar diastereoisomer using tetrabutylammonium fluoride in dry THF gave the diol **28a** (97%) which on treatment with silver



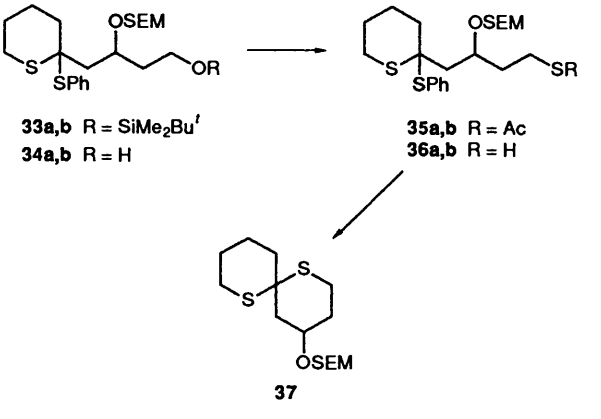
Scheme 3

tetrafluoroborate in aqueous acetonitrile gave the diastereoisomeric monothiospiroacetals **29** and **30**, ratio 94:6, in excellent yield. Deprotection and spirocyclisation of the more polar alkylated tetrahydrothiopyran **27b** similarly gave the monothiospiroacetals **29** and **30**.

Structures were assigned to the spiroacetals **29** and **30** by comparison of their spectroscopic data with those of the analogous spiroacetals **18** and **19**. The major isomer **29** is an analogue of spiroacetal **32** which has been isolated from *Dacus oleae*.[19]

Oxidation of the major isomer **29** gave the ketone **31** which was reduced by sodium borohydride to give the alcohols **29** and **30** in a ratio of *ca.* 33:67 (*cf.* 94:6 after spirocyclisation). Treatment of alcohol **30** with toluene-*p*-sulfonic acid in methanol brought about clean isomerisation, and gave a mixture of **29** and **30**, ratio 95:5, similar to that obtained from spirocyclisation.

Synthesis of Dithiospiroacetals.—The 2-(hydroxyalkyl)-2-phenylthiotetrahydrothiopyran **27a** was converted into its 2-trimethylsilyloxyethoxymethyl ether (SEM-ether) **33**, and the primary hydroxy group deprotected selectively using anhydrous tetrabutylammonium fluoride (TBAF). Treatment of the alcohol **34** so obtained with thioacetic acid under Mitsunobu conditions[20] gave the thioester **35** which was reduced using lithium aluminium hydride to give the thiol **36** (Scheme 4).

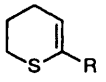


Scheme 4

However, attempts to cyclise the thiol to the dithiospiroacetal **37** using heavy metal reagents gave only modest yields of **37**.

Since lithiated vinyl thioethers have been used as acylcarbanion equivalents,[21] and dihydropyrans have been found to be useful precursors of spiroacetals,[22] the use of the dihydrothiopyran **25**[23] for the synthesis of dithiospiroacetals

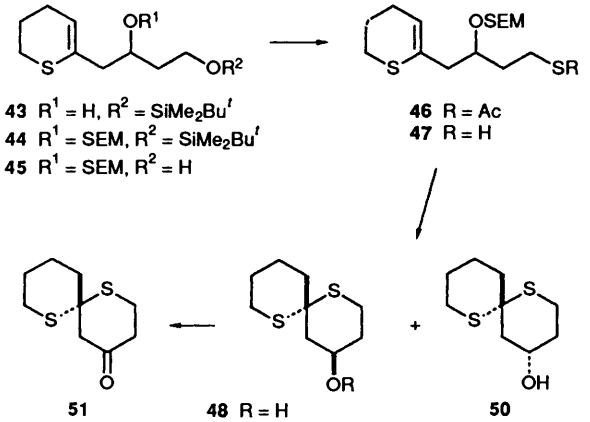
was investigated. Deprotonation of the dihydrothiopyran **25** at −78 °C was found to be more efficient using *sec*-butyllithium than butyllithium–tetramethylethylenediamine. Quenching with D_2O gave the deuteriated dihydrothiopyran **38**, and



38 R = D
39 R = Me
40 R = $PhCH_2$
41 R = PhCHOH
42 R = $Me_2CHCHOH$

addition of methyl iodide or benzyl bromide followed by warming to 0 °C, gave the 2-alkylated dihydrothiopyrans **39**[24] and **40**. Similarly addition of benzaldehyde or 2-methylpropanal to a solution of the lithiated dihydropyran gave the 2-(hydroxyalkyl)dihydrothiopyrans **41** and **42**, all in good yield.

Preliminary attempts to alkylate the lithiated dihydrothiopyran **25** using the epoxides **13** and **14** were unsuccessful. However, in the presence of boron trifluoride–diethyl ether,[25] alkylation was achieved with the epoxide **14** and the 2-(hydroxyalkyl)dihydrothiopyran **43** was isolated (70%). Following protection and selective deprotection of the primary hydroxy substituent, treatment of alcohol **45** with thioacetic acid under Mitsunobu conditions, gave the thioester **46** which was reduced by lithium aluminium hydride to give the thiol **47** (Scheme 5). This was cyclised under acidic conditions to give



43 R^1 = H, R^2 = $SiMe_2Bu^t$
44 R^1 = SEM, R^2 = $SiMe_2Bu^t$
45 R^1 = SEM, R^2 = H

46 R = Ac
47 R = H

51

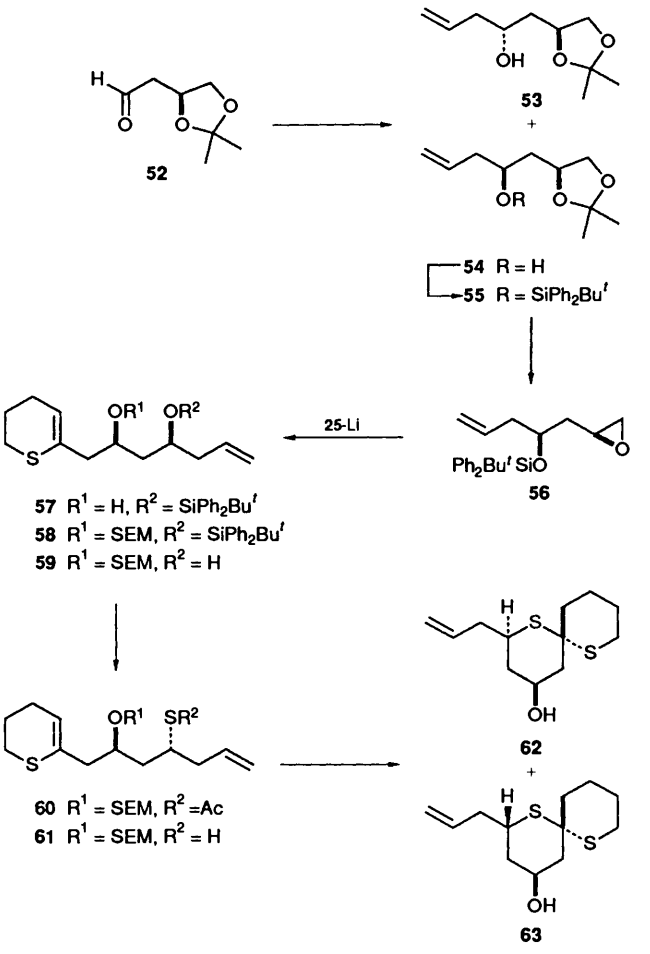
48 R = H
49 R = *p*-$O_2NC_6H_4CO$

50

Scheme 5

a mixture of the 4-hydroxydithiospiroacetals **48** and **50**, ratio 95:5, yield 75%. Oxidation of the mixture of hydroxydithiospiroacetals gave the ketone **51**, and acylation of the major isomer **48** gave the *p*-nitrobenzoate **49** whose structure was established by X-ray diffraction, *vide infra*. The monothiospiroacetals **29** and **30** were also prepared from the (hydroxyalkyl)-dihydrothiopyran **43** by deprotection using tetrabutylammonium fluoride followed by acid catalysed cyclisation.

Finally, in anticipation of syntheses of milbemycin analogues, the more substituted dithiospiroacetals **62**, **63** and **71** were prepared from the dihydrothiopyrans **25** and **65**. Addition of allylmagnesium bromide to the aldehyde **52** gave a mixture of alcohols **53** and **54**[26] (Scheme 6) which were separated by flash chromatography. Protection of **54** as its *tert*-butyldiphenylsilyl ether **55** followed by hydrolysis of the acetal and cyclisation of the diol so obtained gave the epoxide **56**. Alkylation of the lithiated dihydrothiopyran **25** using this epoxide gave the 2-(hydroxyalkyl)dihydrothiopyran **57** which was converted into the thiol **61** by a protection, selective deprotection, Mitsunobu inversion, and reduction sequence. Cyclisation then gave the



52

53 + **54** R = H, **55** R = $SiPh_2Bu^t$

56

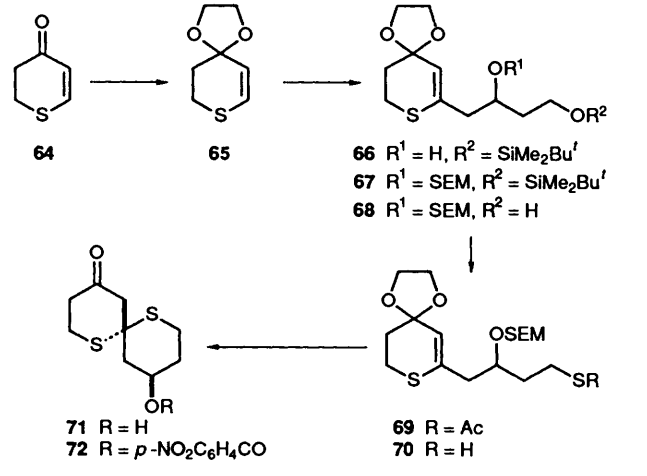
57 R^1 = H, R^2 = $SiPh_2Bu^t$
58 R^1 = SEM, R^2 = $SiPh_2Bu^t$
59 R^1 = SEM, R^2 = H

60 R^1 = SEM, R^2 = Ac
61 R^1 = SEM, R^2 = H

62 + **63**

Scheme 6

2-alkyl-4-hydroxy-1,7-dithiaspiro[5.5]undecane **62**, together with a minor product tentatively identified on the basis of its spectroscopic data as the C-2 epimer **63**, ratio *ca.* 95:5. Both dithiospiroacetals had 4-H signals characteristic of an axial hydrogen. Similarly, alkylation of the dihydrothiopyran **65**[11,12] which was prepared from the thiione **64**, using the epoxide **14**, followed by protecting group interchange and introduction of the thioester, gave **69**, which was reduced to provide the thiol **70** (Scheme 7). This cyclised to the dithiospiroacetal **71** on treatment with acid. The structure of the dithiospiroacetal **71** and the corresponding *p*-nitrobenzoate **72** were established by ^1H NMR spectroscopy.



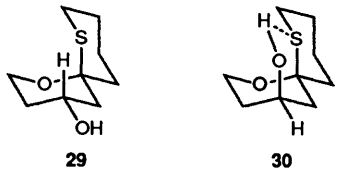
64 **65**

66 R^1 = H, R^2 = $SiMe_2Bu^t$
67 R^1 = SEM, R^2 = $SiMe_2Bu^t$
68 R^1 = SEM, R^2 = H

71 R = H
72 R = *p*-$NO_2C_6H_4CO$

69 R = Ac
70 R = H

Scheme 7



29 30

Fig. 1 Projections showing preferred conformations of spiroacetals **29** and **30**

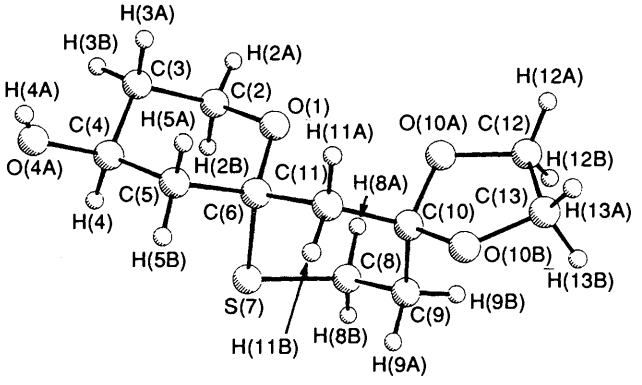


Fig. 2 Projection of the monothiospiroacetal **18** as determined by X-ray crystallography showing the crystallographic numbering scheme used

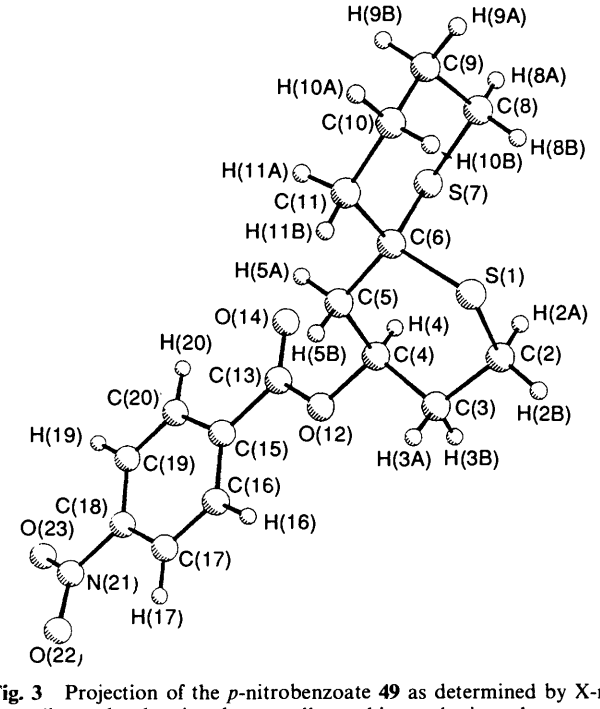


Fig. 3 Projection of the *p*-nitrobenzoate **49** as determined by X-ray crystallography showing the crystallographic numbering scheme used

Structural Studies.—The synthetic work outlined above provided the monothiospiroacetals **18** and **19**, and **29** and **30**, together with the dithiospiroacetals **48**, **50**, **62**, **63** and **71**. Although the spectroscopic data obtained for these compounds established their gross structures, it was difficult to be certain of their configurations at the anomeric centres.

IR studies showed that the major hydroxy-monothiospiroacetal in each series had a broad band, at 3505 cm^{-1} for either **18** or **19**, and at 3401 cm^{-1} for either **29** or **30**, which decreased in intensity and which eventually disappeared on dilution, characteristic of intermolecular hydrogen-bonding. For the minor diastereoisomer in each series, the analogous bands at 3533 and 3524 cm^{-1} did not diminish in intensity at lower concentrations suggestive of intramolecular hydrogen-bonding. These results are consistent with the minor products being **19** and **30**, with intramolecular hydrogen-bonding between the axial hydroxy substituent and the sulfur atom of the monothiospiroacetal, which is axial to maximise anomeric effects, *cf.* Fig. 1. The major products are equatorial alcohols which cannot participate in intramolecular hydrogen-bonding.

The configuration of the major dioxolane substituted monothiospiroacetal was confirmed by an X-ray crystal structure determination. Fig. 2 shows a projection of a molecule of the major isomer in the crystalline state, showing that its stereochemistry corresponds to **18**. The structure of the *p*-nitrobenzoate **49** of the major dithiospiroacetal was also established by X-ray crystallography. Fig. 3 shows that the heteroatoms at the anomeric centre of the thiospiroacetal **49** are axial with the 4-acyloxy substituent equatorial.

The structures of the other mono- and di-thiospiroacetals were established by comparison of their spectroscopic data, specifically ^1H NMR data with those of **18** and **48**. In the 4-substituted spiroacetals, the configuration of the 4-substituent was apparent from the shape and ^1H NMR chemical shift of the multiplet of the 4-hydrogen. Axial hydrogens at C-4 give rise to significantly broader multiplets than equatorial hydrogens and are deshielded by the *cis*-axial anomeric heteroatom.

Conclusions

This work has established synthetic routes to mono- and di-thiospiroacetals which do not involve cyclisations of mono- and di-mercaptan substituted ketones. Rather the alkylation of a preformed sulfur containing ring, followed by functional group modification and cyclisation, provides access to the thiospiroacetal. This chemistry is now being used to prepare analogues of biologically active spiroacetals.

All the cyclisations investigated were stereoselective with respect to the configuration at the anomeric centre, with the major product corresponding to that expected on the basis of the anomeric effect.[3] Indeed apart from the dioxolane substituted monothiospiroacetals, the stereoselectivity was 95:5 or better. For the monothiospiroacetals **29** and **30** this would appear to be due to thermodynamic control since treatment of the minor isomer **30** with acid gave a mixture of products similar in composition to that obtained from the cyclisation.

Experimental

All non-aqueous reactions were performed under an atmosphere of dry argon or nitrogen. ^1H NMR spectra were recorded on Varian Unity 500, Bruker AC 300, Varian Gemini 200, and Bruker AC 80 spectrometers. IR spectra were measured on a Perkin-Elmer 1710FT spectrometer as evaporated films, unless otherwise stated. Mass spectra were recorded on Kratos MS20 and MS25 spectrometers using either electron impact (EI) or chemical ionisation (CI) modes. Optical rotations were measured on an Optical Activity AA-100 polarimeter. M.p.s were determined on a Kofler block, and are uncorrected. All solvents were dried and distilled before use. Light petroleum refers to the fraction which distils at 40–60 °C, and ether to diethyl ether. Flash chromatography was carried out using May and Baker Sorbsil C60 40–60 μ.

7-(4-*Benzyloxy*-2-*hydroxybutyl*)-7-*phenylthio*-1,4-*dioxa*-8-*thiaspiro*[4,5]*decane* **15a**, **b**.—Butyllithium (7.87 mmol) was added to a stirred solution of dithioacetal **10**[11,12] (1.81 g, 6.74 mmol) in THF (30 cm^3) at −35 °C. After 0.5 h, epoxide **13**[13] (1.00 g, 5.60 mmol) was added, and the reaction mixture was stirred at −35 °C for 1.75 h and then at −20 °C for 1.5 h before being quenched with water (20 cm^3) and diluted with ether (60

cm^3). The aqueous phase was extracted with ether (3 × 40 cm^3) and the combined extracts were washed with brine (30 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography of the residue [light petroleum–ether (3:1) and ether] afforded the *title alcohols* (96%).

15a (1.42 g) (Found: M − PhS, 337.1466. $C_{18}H_{25}SO_4$ requires *M*, 337.1474); ν_{max}/cm^{-1} 3460, 3080, 3021, 1107, 752 and 695; δ_H(300 MHz; $CDCl_3$) 1.65–1.95 (5 H, m, 10-CH_2, 1′-H and 3′-CH_2), 2.03 and 2.24 (each 1 H, d, *J* 14.0, 6-H), 2.42 (1 H, dd, *J* 15.0, 7.0, 1′-H), 2.75–2.98 (2 H, m, 9-CH_2), 3.59–3.74 (2 H, m, 4′-CH_2), 3.80 (1 H, d, *J* 1.5, OH), 3.85–4.01 (4 H, m, 2-CH_2 and 3-CH_2), 4.32–4.44 (1 H, m, 2′-H), 4.52 (2 H, s, PhCH_2), 7.23–7.47 (8 H, ArH) and 7.57–7.68 (2 H, m, ArH); *m*/*z* (CI, NH_3) 337 (M^+ − PhS, 69%).

15b (1.00 g) (Found: M − PhS, 337.1485. $C_{18}H_{25}SO_4$ requires *M*, 337.1474); ν_{max}/cm^{-1} 3472, 3080, 3024, 1106, 1027, 910, 736 and 696; δ_H(300 MHz; $CDCl_3$) 1.54–2.04 (5 H, m, 10-CH_2, 1′-H and 3′-CH_2), 2.08–2.12 (2 H, m, 6-H and 1′-H), 2.35 (1 H, d, *J* 13.5, 6-H), 2.72–2.96 (2 H, m, 9-CH_2), 3.50 (1 H, d, *J* 3.5, 2′-OH), 3.65 (2 H, m, 4′-CH_2), 3.85–4.00 (4 H, m, 2-H and 3-H), 4.33–4.47 (1 H, m, 2′-H), 4.52 (2 H, s, PhCH_2), 7.23–7.43 (8 H, m, ArH) and 7.58–7.68 (2 H, m, ArH); *m*/*z* (CI, NH_3) 337 (M^+ − PhS, 100%).

7-(4-tert-*Butyldimethylsilyloxy*-2-*hydroxybutyl*)-7-*phenylthio*-1,4-*dioxa*-8-*thiaspiro*[4.5]*decane* **16a**, **b**.—Using the procedure outlined above, the dithioacetal **10**[11,12] (3.10 g, 11.6 mmol) and epoxide **14**[14] (1.95 g, 9.63 mmol) gave the *title alcohols* (93%) which could be partially separated by flash chromatography.

16a (Found: M − PhS, 361.1865. $C_{17}H_{33}O_4SSi$ requires *M*, 361.1869); ν_{max}/cm^{-1} 3487, 3055, 1255, 1106, 837, 777 and 752; δ_H(300 MHz; $CDCl_3$) 0.09 (6 H, s, SiBu^t*Me*$_2$), 0.91 (9 H, s, Si*Bu*^{t}Me$_2$), 1.53–1.96 (5 H, m, 10-CH_2, 1′-H and 3′-CH_2), 2.05 and 2.25 (each 1 H, d, *J* 14.0, 6-H), 2.41 (1 H, dd, *J* 16.0, 9.0 H_2, 1′-H), 2.82–2.96 (2 H, m, 9-CH_2), 3.71–3.82 (3 H, m, 2′-OH and 4′-CH_2), 3.87–4.01 (4 H, m, 2-CH_2 and 3-CH_2), 4.30–4.42 (1 H, m, 2′-H), 7.29–7.46 (3 H, m, ArH) and 7.58–7.68 (2 H, m, ArH); *m*/*z* (EI, NH_3) 361 (M^+ − PhS, 89%).

16b (Found: M − PhS, 361.1862. $C_{17}H_{33}O_4SSi$ requires *M*, 361.1869); ν_{max}/cm^{-1} 3480, 3060, 1255, 1106, 837, 777 and 693; δ_H(300 MHz; $CDCl_3$) 0.09 (6 H, s, SiBu^t*Me*$_2$), 0.92 (9 H, s, Si*Bu*^{t}Me$_2$), 1.50–1.70 (1 H, m), 1.72–1.98 (3 H, m), 2.01–2.11 (1 H, m), 2.16 and 2.31 (each 1 H, d, *J* 14.0, 6-H), 2.72–3.03 (3 H, m, 9-CH_2 and 1′-H), 3.61 (1 H, d, *J* 3.0, 2′-OH), 3.82 (2 H, m, 4′-CH_2), 3.89–4.05 (4 H, m, 2-CH_2 and 3-CH_2), 4.40 (1 H, m, 2′-H), 7.28–7.41 (3 H, m, ArH) and 7.60–7.65 (2 H, m, ArH); *m*/*z* (CI, NH_3) 361 (M^+ − PhS, 58%).

7-(2,4-*Dihydroxybutyl*)-7-*phenylthio*-1,4-*dioxa*-8-*thiaspiro*[4.5]*decane* **17a**, **b**.—Tetrabutylammonium fluoride (1.0 mol dm^{-3} in THF; 3.95 cm^3, 3.95 mmol) was added to a stirred solution of the less polar alcohol **16a** (928 mg, 1.97 mmol) in THF at 0 °C. The reaction mixture was stirred at ambient temperature for 18 h, quenched with saturated aqueous ammonium chloride (15 cm^3) and diluted with ethyl acetate (30 cm^3). The aqueous phase was separated and extracted with ethyl acetate (3 × 20 cm^3), and the combined organic phase was washed with brine (10 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure. Chromatography of the residue [light petroleum–ethyl acetate (2:1) and ethyl acetate] gave the *diol* **17a** as a viscous oil which solidified upon storage (691 mg, 98%) (Found: M^+ − PhS, 247.1008. $C_{11}H_{17}SO_4$ requires *M*, 247.1004); ν_{max}/cm^{-1} 3420, 3046, 1474, 1171, 1107, 1068, 754 and 693; δ_H(300 MHz; C_6D_6) 1.45–1.67 (3 H, m, 10-CH_2 and 3′-H), 1.79 (1 H, m, 3′-H), 1.92 (1 H, dd, *J* 15.5, 1.5, 1′-H), 2.25 and 2.28 (each 1 H, d, *J* 15, 6-H), 2.32 (1 H, m, 9-H), 2.70–2.88 (3 H, m, 9-H, 1′-H and OH), 3.30–3.44 (4 H, m, 2-CH_2 and 3-CH_2), 3.83 (2 H, m, 4′-H), 4.13 (1 H, br s, OH), 4.64 (1 H, m, 2′-H), 7.05 (3 H, m, ArH) and 7.72 (2 H, m, ArH); *m*/*z* (CI, NH_3) 247 (M^+ − PhS, 100%).

The more polar alcohol **16b** (900 mg, 1.91 mmol) similarly gave the *diol* **17b** as a viscous oil (623 mg, 92%); ν_{max}/cm^{-1} 3418, 3056, 1171, 1107, 1068 and 754; δ_H(300 MHz; C_6D_6) 1.41–1.90 (4 H, m, 10-CH_2 and 3′-CH_2), 2.16 (1 H, d, *J* 16.0, 1′-H), 2.25–2.71 (5 H, m, 6-CH_2, 9-H, 1′-H and OH), 2.80 (1 H, m, 9-H), 3.21–3.52 (4 H, m, 2-CH_2 and 3-CH_2), 3.82 (3 H, m, 4′-CH_2 and OH), 4.68 (1 H, m, 2′-H), 7.10 (3 H, m, ArH) and 7.82 (2 H, m, ArH); *m*/*z* (FAB) 247 (M^+ − PhS, 92%), 154 (100) and 136 (84).

1,4,8-*Trioxa*-13-*thiadispiro*[4.1.5.3]*pentadecan*-11-*ols* **18** *and* **19**.—Silver nitrate (128 mg, 0.754 mmol) was added to a stirred solution of the diol **17a** (244 mg, 0.685 mmol) and triethylamine (191 cm^3, 1.37 mmol) in 10% aqueous acetonitrile (19 cm^3). After 5 min the mixture was diluted with ethyl acetate (30 cm^3), filtered through Celite and the filter-cake washed with ethyl acetate (20 cm^3). The combined filtrates were concentrated under reduced pressure and the residue dissolved in ethyl acetate (30 cm^3), washed with water (10 cm^3) and the aqueous phase extracted with ethyl acetate (3 × 15 cm^3). The combined extracts were washed with brine (10 cm^3), dried (Na_2SO_4) and concentrated under reduced pressure. Chromatography of the residue (3% methanol in dichloromethane) separated the *spiroacetals* (93%).

The less polar isomer, **19** (64 mg) (Found: M^+, 246.0922. $C_{11}H_{18}O_4S$ requires *M*, 246.0926); $\nu_{max}(CCl_4)/cm^{-1}$ 3533, 3480, 1198, 1109, 1055 and 1034; δ_H(300 MHz; C_6D_6) 1.43 (1 H, m, 10-H_{eq}), 1.50–1.67 (1 H, m, 10-H_{ax}), 1.58 (1 H, dd, *J* 15.0, 3.6, 12-H_{ax}), 1.80–2.00 (2 H, m, 15-CH_2), 2.08 (1 H, ddd, *J* 15.0, 2.0, 1.8, 12-H_{eq}), 2.11 and 2.22 (each 1 H, d, *J* 13.5, 6-H), 2.25 (1 H, ddd, *J* 13.7, 6.0, 3.3, 14-H_{eq}), 2.81 (1 H, br s, 11-OH), 2.95 (1 H, ddd, *J* 13.7, 9.0, 4.0, 14-H_{ax}), 3.40–3.68 (5 H, m, 2-CH_2, 3-CH_2 and 9-H_{eq}), 3.89 (1 H, m, 11-H_{eq}) and 4.26 (1 H, td, *J* 12.0, 3.0, 9-H_{ax}); *m*/*z* EI 246 (M^+, 8.3%), 132 (92), 99 (100) and 86 (89); the more polar isomer **18** (90 mg) was a crystalline solid, m.p. 128.5–129.5 °C (Found: M^+, 246.0923. $C_{11}H_{18}O_4S$ requires *M*, 246.0926); $\nu_{max}(CCl_4)/cm^{-1}$ 3622, 3505, 1252, 1111, 1073, 1033 and 970; δ_H(300 MHz; C_6D_6) 1.00 (1 H, br s, OH), 1.43–1.59 (1 H, m, 10-H_{ax}), 1.57 (1 H, t, *J* 12.0, 12-H_{ax}), 1.72 (1 H, m, 10-H_{eq}), 2.10–2.19 (2 H, m, 15-CH_2), 2.32 (1 H, ddd, *J* 12.0, 5.0, 2.0, 12-H_{eq}), 2.33 (1 H, d, *J* 14.0, 6-H), 2.40 (1 H, dt, *J* 14, 4.0, 14-H_{eq}), 2.47 (1 H, d, *J* 14.0, 6-H), 3.20 (1 H, ddd, *J* 14, 9.5, 5, 14-H_{ax}), 3.60–3.92 (5 H, m, 2-CH_2, 3-CH_2 and 9-H_{eq}), 4.04–4.18 (1 H, m, 11-H_{ax}) and 4.18 (1 H, td, *J* 12.0, 2.5, 9-H_{ax}); *m*/*z* EI 246 (M^+, 11%), 185 (15), 132 (92), 99 (100) and 86 (80).

(4RS,6RS)-4-*Hydroxy*-1-*oxa*-7-*thiaspiro*[5.5]*undecan*-10-*one* **21**. If silver tetrafluoroborate was substituted for silver nitrate in the above procedure or if triethylamine was not added varying amounts of compound **21** were isolated (Found: M^+, 202.0663. $C_9H_{14}O_3S$ requires *M*, 202.0663); ν_{max}/cm^{-1} 3403, 1712, 1067, 1034, 961 and 792; δ_H(300 MHz; C_6D_6) 1.11–1.30 (2 H, m, 3-H_{ax} and 5-H_{ax}), 1.48 (1 H, m, 3-H_{eq}), 1.94 (1 H, ddd, *J* 14.0, 4.5, 2, 5-H_{eq}), 2.01–2.19 (2 H, m, 8-H and 9-H), 2.40–2.63 (2 H, m, 8-H and 9-H), 2.41 (1 H, d, *J* 14.0, 11-H), 2.71 (1 H, dd, *J* 14.0, 1, 11-H), 3.45 (1 H, ddd, *J* 11.5, 5, 1.5, 2-H_{eq}), 3.65 (1 H, ddd, *J* 11.5, 10.1, 2.5, 2-H_{ax}) and 3.82 (1 H, tt, *J* 11, 4.2, 4-H_{ax}); *m*/*z* EI 202 (M^+, 16%), 184 (21), 169 (42), 151 (28) and 141 (100).

Treatment of the Diol **17a** *with Aqueous Acid*.—A mixture of the diol **17a** (89 mg, 0.25 mmol) and aqueous HCl (3.5 mol dm^{-3}; 0.5 cm^3) in acetone (2.5 cm^3) was heated under reflux under nitrogen for 5 h. The reaction mixture was cooled, diluted with water (5 cm^3) and extracted with ether (3 × 10 cm^3). Chromatography of the residue (light petroleum–ethyl acetate) gave several products including **22**–**24**.

3-(4-*Hydroxybutenyl*)-4-*thiacyclohex*-2-*enone* **22**. ν_{max}/cm^{-1} 3384, 1647, 1627, 1539, 1331, 1286, 1181, 1047 and 960; δ_H(300 MHz; C_6D_6) 1.98 (2 H, m, 3'-H), 2.34 (4 H, m, 5-CH_2 and 6-CH_2), 3.22 (2 H, m, 4'-CH_2), 5.90 (1 H, d, *J* 15.5, 1'-H), 6.22 (1 H, s, 3-H) and 6.32 (1 H, dt, *J* 15.5, 7.5, 2'-H).

3-(4-*Hydroxy*-2-*phenylthiobutyl*)-4-*thiacyclohex*-2-*enone* **23**. ν_{max}/cm^{-1} 3411, 3054, 1646, 1567, 1329, 1180, 1044, 748 and 694; δ_H(300 MHz; $CDCl_3$) 1.00 (1 H, m, OH), 1.54 and 1.71 (each 1 H, m, 3'-H), 2.18–2.33 (4 H, m, 5-CH_2 and 6-CH_2), 2.37 and 2.51 (each 1 H, dd, *J* 9.5, 7.5, 1'-H), 3.55 (1 H, m, 2'-H), 3.68 (2 H, m, 4'-CH_2), 6.22 (1 H, s, 3-H), 6.95–7.09 (3 H, m, ArH) and 7.49 (2 H, m, ArH).

4-*Phenylthio*-1-*oxa*-7-*thiaspiro*[5.5]*undecan*-10-*one* **24**. ν_{max}/cm^{-1} 3057, 1717, 1097, 1061, 745 and 693; δ_H(300 MHz; $CDCl_3$) 1.49–1.70 (1 H, m, 3-H_{ax}), 1.61 (1 H, t, *J* 13, 5-H_{ax}), 1.90 (1 H, m, 3-H_{eq}), 2.25 (1 H, ddd, *J* 13.0, 4.0, 2.0, 5-H_{eq}), 2.53–2.95 (4 H, m, 8-CH_2 and 9-CH_2), 2.67 and 2.82 (each 1 H, d, *J* 13.5, 11-H), 3.55 (1 H, tt, *J* 12.2, 4, 4-H_{ax}), 3.75 (1 H, ddd, *J* 12.0, 5.0, 1.5, 2-H_{eq}), 3.93 (1 H, td, *J* 12, 2.5, 2-H_{ax}) and 7.23–7.45 (5 H, m, ArH); *m*/*z* (CI, NH_3) 312 (MNH_4^+, 36.9%) and 295 (32.6).

1,4,8-*Trioxa*-13-*thiadispiro*[4.1.5.3]*pentadecan*-11-*one* **20**.—Pyridinium dichromate (138 mg, 0.366 mmol) and pyridinium trifluoroacetate (19 mg, 0.098 mmol) were added to a stirred solution of the spiroacetals **18** and **19** (60 mg, 0.244 mmol) in dichloromethane (2 cm^3). After 4 h a further portion of pyridinium dichromate (138 mg, 0.366 mmol) and pyridinium trifluoroacetate (19 mg, 0.098 mmol) was added. After a further 16 h the reaction mixture was diluted with ethyl acetate (10 cm^3) and filtered through Celite and the filter-cake was washed with ethyl acetate (20 cm^3). The combined filtrates were concentrated under reduced pressure and chromatography of the residue [ethyl acetate–light petroleum (2:1)] gave the *ketone* **20** as white crystals (50 mg, 84%), m.p. 117.5–118.5 °C (Found: M^+, 244.0775. $C_{11}H_{16}O_4S$ requires *M*, 244.0769); ν_{max}/cm^{-1} 1721, 1248, 1175, 1109, 1070, 1027, 937 and 801; δ_H(300 MHz; C_6D_6) 1.71–1.90 (2 H, m), 1.95–2.11 (4 H, m), 2.17 (1 H, d, *J* 14.7, 12-H), 2.23 (1 H, dd, *J* 14.0, 1.0, 6-H), 2.59 (1 H, d, *J* 14.7, 12-H), 2.82 (1 H, ddd, *J* 14.0, 11.0, 3.4, 14-H_{ax}), 3.40–3.72 (5 H, m, 2-CH_2, 3-CH_2 and 9-H_{eq}) and 4.15 (1 H, m, 9-H_{ax}); *m*/*z* (CI, NH_3) 244 (MH^+, 100%).

2-*Phenylthiotetrahydro*-2H-*thiopyran* **26**.—A mixture of dihydrothiopyran **25**[23] (3.4 g, 30 mmol), freshly distilled thiophenol (4.62 cm^3, 45 mmol), dihydroquinone (330 mg, 9 mmol) and toluene-*p*-sulfonic acid (200 mg, 1.05 mmol) was heated under reflux in dry, degassed benzene (120 cm^3) for 2 h. After cooling, the reaction mixture was diluted with ether (100 cm^3), washed with water (30 cm^3), 10% aqueous potassium hydroxide (30 cm^3) and water (30 cm^3). The combined aqueous phases were extracted with ether (3 × 50 cm^3) and the combined extracts were washed with brine (50 cm^3), dried ($MgSO_4$), and concentrated under reduced pressure. Flash chromatography of the residue [light petroleum–ether (50:1)] followed by distillation (Kugelrohr) afforded the title compound[18] as a pale yellow liquid (6.44 g, 90%), b.p. 100 °C/0.2 mmHg (Found: M^+, 210.0533. $C_{11}H_{14}S_2$ requires *M*, 210.0537); ν_{max}/cm^{-1} 3056, 1583, 1479, 1438, 1268, 953, 741 and 691; δ_H(300 MHz; $CDCl_3$) 1.48–1.62 (1 H, m), 1.78–2.02 (4 H, m), 2.18–2.29 (1 H, m), 2.55–2.63 and 2.83–2.94 (each 1 H, m, 6-H), 4.28 (1 H, dd, *J* 7.5, 2.5, 2-H), 7.22–7.40 (3 H, m, ArH) and 7.47–7.52 (2 H, ArH); *m*/*z* (EI) 210 (M^+, 85%).

2-(4-tert-*Butyldimethylsilyloxy*-2-*hydroxybutyl*)-2-*phenylthiotetrahydro*-2H-*thiopyran* **27a**, **b**.—Butyllithium (4.76 mmol) was added dropwise to a stirred solution of the dithioacetal **26** (1.00 g, 4.76 mmol) in THF (10 cm^3) at −78 °C and the reaction mixture stirred at this temperature for 1.5 h. The epoxide **14**[14] (801 mg, 3.97 mmol) was added as a solution in THF (8 cm^3) and the reaction mixture allowed to slowly warm to 0 °C over a period of 5 h. Work-up as outlined above, and flash chromatography [light petroleum–ether (15:1)], gave the *title alcohols* (91%) together with a mixture of the two isomers (400 mg).

The less polar diastereoisomer **27a** (680 mg); ν_{max}/cm^{-1} 3483, 1472, 1438, 1255, 1091, 836, 778 and 750; δ_H(200 MHz; C_6D_6) 0.03 and 0.05 (each 3 H, s, SiMe), 0.95 (9 H, s, Bu^t), 1.21–1.45 (3 H, m), 1.51–2.05 (6 H, m), 2.10–2.24 (2 H, m), 3.06 (1 H, m, 6-H), 3.67–3.88 (3 H, m, 4'-CH_2 and 2'-OH), 4.73 (1 H, m, 2'-H), 7.03 (3 H, m, ArH) and 7.73 (2 H, m, ArH); *m*/*z* (EI) 302 (M^+ − PhSH, 1.4%).

The more polar diastereoisomer **27b** (394 mg); ν_{max}/cm^{-1} 3487, 1472, 1438, 1255, 1091, 837, 778 and 749; δ_H(200 MHz; C_6D_6) 0.09 (6 H, s, $SiMe_2$), 1.00 (9 H, s, Bu^t), 1.28–1.74 (6 H, m), 1.80–2.09 (3 H, m), 2.14–2.32 (2 H, m), 2.88–3.05 (1 H, m, 6-H), 3.45 (1 H, d, *J* 3.0, 2'-OH), 3.52–3.88 (2 H, m, 4'-CH_2), 4.72 (1 H, br t, *J* 8.4, 2'-H), 7.10 (3 H, m, ArH) and 7.69 (2 H, m, ArH); *m*/*z* (EI) 302 (M^+ − PhSH, 2.5%).

2-(2,4-*Dihydroxybutyl*)-2-*phenylthiotetrahydro*-2H-*thiopyran* **28a**, **b**.—The less polar alcohol **27a** (670 mg, 1.63 mmol) was deprotected using tetrabutylammonium fluoride as outlined above to give the *diol* **28a** as a white crystalline solid (470 mg, 97%), m.p. 92.5–93.5 °C [Found: C, 60.1; H, 7.1; S, 21.6%. $C_{15}H_{22}O_2S_2$ requires C, 60.4; H, 7.4; S, 21.5%; Found: M, (M − PhS), 189.0954. $C_{14}H_{17}O_2S$ requires *M*, 189.0949]; ν_{max}/cm^{-1} 3384, 3057, 1474, 1438, 1067, 750 and 693; δ_H(300 MHz; C_6D_6) 1.28–1.48 (3 H, m), 1.50–1.76 (5 H, m), 1.98 (1 H, m), 2.12–2.31 (3 H, m, 6-H, 1'-H and OH), 3.13 (1 H, ddd, *J* 15.0, 10.5, 3.6, 6-H), 3.76 (2 H, m, 4'-H), 4.02 (1 H, br s, OH), 4.63 (1 H, m, 2'-H), 7.10 (3 H, m, ArH) and 7.75 (2 H, m, ArH); *m*/*z* (CI, NH_3) 189 (M^+ − PhS, 100%).

Deprotection of the more polar alcohol **27b** (380 mg, 0.92 mmol) using the same procedure gave the *diol* **28b** as a white crystalline solid (279 mg, 100%), m.p. 98.5–99 °C (Found: C, 60.3; H, 7.3. $C_{15}H_{22}O_2S_2$ requires C, 60.4; H, 7.4%); ν_{max}/cm^{-1} 3374, 1474, 1438, 1066, 750 and 693; δ_H(300 MHz; C_6D_6) 1.31 (3 H, m), 1.52–1.61 (1 H, m), 1.62–1.73 (2 H, m), 1.80–1.91 (3 H, m), 2.16 (1 H, dd, *J* 15.0, 9.0, 1'-H), 2.28 (1 H, m, 6-H), 2.05–2.45 (1 H, br s, OH), 2.87 (1 H, m, 6-H), 3.60 (1 H, br s, OH), 3.75 (2 H, m, 4'-CH_2), 4.61 (1 H, m, 2'-H), 7.11 (3 H, m, ArH) and 7.70 (2 H, m, ArH); *m*/*z* (CI, NH_3) 189 (M^+ − PhS, 100%).

1-*Oxa*-7-*thiaspiro*[5.5]*undecan*-4-*ols* **29** *and* **30**.—A solution of silver tetrafluoroborate (343 mg, 1.76 mmol) in acetonitrile (4 cm^3) was added to a solution of the less polar diol **28a** (375 mg, 1.26 mmol) in aqueous acetonitrile (10%; 68 cm^3). After 10 min the reaction mixture was diluted with ethyl acetate (50 cm^3) and hydrogen sulfide gas was bubbled through the solution for 30 s; it was then filtered through Celite. The filter-cake was washed with ethyl acetate (50 cm^3), and the combined filtrates were concentrated to give a residue which was partitioned between ethyl acetate and water. The organic phase was concentrated under reduced pressure, and chromatography of the residue (3% methanol in dichloromethane) gave the *title monothiospiroacetals* (99%).

The less polar diastereoisomer **30** (14 mg), was a colourless oil, (Found: M^+, 188.0870. $C_9H_{16}O_2S$ requires *M*, 188.0871); ν_{max}(CCl_4)/cm^{-1} 3524, 1436, 1251, 1197, 1169, 1095, 1054 and 947; δ_H(300 MHz; C_6D_6) 1.34–2.02 (11 H, m), 2.66 (1 H, ddd, *J* 13.4, 11.8, 3.4, 8-H_{ax}), 2.73 (1 H, d, *J* 9.0, 4-OH), 3.48 (1 H, ddd, *J* 12.0, 5.2, 3.1, 2-H_{eq}), 3.88 (1 H, m, 4-H_{eq}) and 4.21 (1 H, td, *J* 12.0, 3.8, 2-H_{ax}); *m*/*z* (CI, NH_3) 206 (MNH_4^+, 15%) and 189 (MH^+, 90).

The more polar diastereoisomer **29** (220 mg) was a white crystalline solid, m.p. 76.5–77.5 °C (Found: C, 57.4; H, 8.8; S,

17.3%; M, 188.0876. $C_9H_{16}O_2S$ requires C, 57.4; H, 8.6; S, 17.0%; *M*, 188.0871); $\nu_{max}(CCl_4)/cm^{-1}$ 3623, 3401, 1254, 1103, 1078, 1039 and 964; δ_H(300 MHz; C_6D_6) 1.17 (1 H, br s, 4-OH), 1.29–1.74 (6 H, m, 3-CH_2, 5-H_{ax}, 9-CH_2 and 10-H), 1.74–2.04 (3 H, m, 11-CH_2 and 10-H), 2.04–2.15 (2 H, m, 5-H_{eq} and 8-H_{eq}), 2.64 (1 H, td, *J* 12.9, 2.9, 8-H_{ax}), 3.66 (1 H, ddd, *J* 12.0, 5.2, 1.7, 2-H_{eq}), 3.97 (1 H, tt, *J* 11.4, 5.0, 4-H_{ax}) and 4.03 (1 H, m, 2-H_{ax}); *m/z* (CI, NH_3) 189 (MH^+, 100%).

Toluene-*p*-sulfonic acid (1 mg, 0.005 mmol) was added to a stirred solution of the spiroacetal **30** (10 mg, 0.052 mmol) in methanol (0.5 cm^3). After 5 h work-up and filtration through a plug of silica gave a mixture of the monothiospiroacetals **29** and **30** (10 mg), ratio 95:5 (200 MHz ^1H NMR).

1-*Oxa*-7-*thiaspiro*[5.5]*undecan*-4-*one* **31**.—Pyridinium dichromate (330 mg, 0.878 mmol) and pyridinium trifluoroacetate (23 mg, 0.117 mmol) were added to a stirred solution of the monothiospiroacetal **29** (55 mg, 0.293 mmol) in dichloromethane (3 cm^3). After 16 h the reaction mixture was diluted with ethyl acetate (10 cm^3), filtered through Florosil and the filter-cake washed with ethyl acetate (20 cm^3). The combined filtrates were concentrated under reduced pressure and chromatography of the residue [light petroleum–ethyl acetate (3:1)] gave the *title ketone* **31** as a colourless oil (37 mg, 68%) (Found: M^+, 186.0712. $C_9H_{14}O_2S$ requires *M*, 186.0714); ν_{max}/cm^{-1} 1716, 1254, 1071 and 948; δ_H(300 MHz; C_6D_6) 1.31–1.48 (2 H, m), 1.53–1.66 (2 H, m), 1.72–2.13 (6 H, m), 2.42–2.53 (2 H, m, 8-CH_2), 3.63 (1 H, m, 2-H_{eq}) and 4.18 (1 H, m, 2-H_{ax}); *m/z* (CI, NH_3) 204 (MNH_4^+, 10%), 187 (MH^+, 100).

Sodium borohydride (30.5 mg, 0.806 mmol) was added to a solution of the ketone **31** (15 mg, 0.081 mmol) in ethanol (1 cm^3) and the reaction quenched after 1 h by the addition of water (3 cm^3). Work-up gave the spiroacetal **30** (10.0 mg) and the more polar spiroacetal **29** (5.0 mg).

6-*Methyl*-3,4-*dihydro*-2H-*thiopyran* **39**.—*sec*-Butyllithium (1.54 mmol) was added dropwise to a stirred solution of dihydrothiopyran **25**[23] (100 mg, 1.0 mmol) in THF (3 cm^3) at −78 °C and the reaction mixture maintained at this temperature for a further 1 h. Methyl iodide (0.1 cm^3, 1.6 mmol) was added and the reaction mixture warmed slowly to ambient temperature, quenched with water (5 cm^3) and diluted with ether (10 cm^3). The aqueous phase was separated and extracted with ether (3 × 10 cm^3) and the combined extracts were washed with brine (5 cm^3), dried ($MgSO_4$) and concentrated to give the title compound[24] as a yellow oil (120 mg, 100%) (Found: M^+, 114.0502. $C_6H_{10}S$ requires *M*, 114.0503); δ_H(80 MHz; $CDCl_3$) 1.65–2.30 (7 H, m, 3-CH_3, 4-CH_2 and Me), 2.85 (2 H, m, 2-CH_2) and 5.45 (1 H, m, 5-H); *m/z* (EI) 114 (M^+, 20%).

6-*Benzyl*-3,4-*dihydro*-2H-*thiopyran* **40**.—Using the procedure outlined above, the dihydrothiopyran **25**[23] (120 mg, 1.20 mmol) and benzyl bromide (125 mm^3, 1.04 mmol) gave, after 10 h at 0 °C and chromatography (light petroleum), the *title compound* as a colourless oil (189 mg, 95%) (Found: M^+, 190.0817. $C_{12}H_{14}S$ requires *M*, 190.0816); ν_{max}/cm^{-1} 3061, 3026, 1632, 1495, 1434, 1272 and 1078; δ_H(300 MHz; $CDCl_3$) 1.92 (2 H, m, 3-CH_2), 2.18 (2 H, m, 4-CH_2), 2.85 (2 H, m, 2-CH_2), 3.72 (2 H, s, PhCH_2), 5.58 (1 H, tt, *J* 4.2, 1, 5-H) and 7.25–7.50 (5 H, m, ArH); *m/z* (EI) 190 (M^+, 100%).

6-(α-*Hydroxybenzyl*)-3,4-*dihydro*-2H-*thiopyran* **41**.—Prepared using the above procedure (85%) (Found: M^+, 206.0761. $C_{12}H_{14}OS$ requires *M*, 206.0765); ν_{max}/cm^{-1} 3398, 3061, 3028, 1632, 1451, 1013 and 973; δ_H(300 MHz; $CDCl_3$) 1.95 (2 H, m, 3-CH_2), 2.25 (3 H, m, 4-CH_2 and OH), 2.35 (2 H, m, 2-CH_2), 5.25 (1 H, d, *J* 4.4, C*H*Ph), 5.91 (1 H, br t, *J* 4.5, 5-H) and 7.22–7.55 (5 H, m, ArH); *m/z* (EI) 206 (M^+, 100%) and 189 (M^+ − 17, 51).

6-(α-*Hydroxy*-2-*methylpropyl*)-3,4-*dihydro*-2H-*thiopyran* **42**.—Prepared using the above procedure (74%) (Found: M^+, 172.0921. $C_9H_{16}OS$ requires *M*, 172.0922); ν_{max}/cm^{-1} 3433, 1632, 1468, 1015 and 974; δ_H(300 MHz; $CDCl_3$) 0.89 and 1.02 (each 3 H, d, *J* 7.5, Me), 1.79 (1 H, d, *J* 5, OH), 1.80–2.15 (3 H, m, 3-CH_2 and 2′-H), 2.20 (2 H, m, 4-CH_2), 2.87 (2 H, m, 2-CH_2), 3.63 (1 H, dd, *J* 8.5, 5.0, 1′-H) and 5.75 (1 H, t, *J* 4.5, 5-H); *m/z* (CI, NH_3) 190 (MNH_4^+, 13%) and 173 (MH^+, 100%).

6-(4-tert-*Butyldimethylsilyloxy*-2-*hydroxybutyl*)-3,4-*dihydro*-2H-*thiopyran* **43**.—*sec*-Butyllithium (20.3 mmol) was added dropwise to a stirred solution of the dihydrothiopyran **25**[23] (1.98 g, 19.8 mmol) in THF (20 cm^3) at −78 °C and the mixture was then added *via* a cannula to a solution of boron trifluoride–diethyl ether (2.44 cm^3, 19.80 mmol) in THF (25 cm^3) at −78 °C. The epoxide **14**[14] (2.00 g, 9.90 mmol) was added and the reaction mixture stirred at −78 °C for a further 0.5 h before being quenched with saturated aqueous sodium hydrogen carbonate (50 cm^3). Ether extraction and chromatography [light petroleum–ether (4:1)] gave the *title compound* **43** as a colourless oil (2.18 g, 73%) (Found: (M^+ − OH, 285.1721. $C_{15}H_{29}OSSi$ requires *M*, 285.1708); ν_{max}/cm^{-1} 3473, 1630, 1254, 1090, 836 and 776; δ_H(300 MHz; $CDCl_3$) 0.07 (6 H, s, $SiMe_2$), 0.90 (9 H, s, Bu^t), 1.52–1.76 (2 H, m, 3′-CH_2), 1.87–2.00 (2 H, m, 3-CH_2), 2.10–2.22 (2 H, m, 4-CH_2), 2.22 (1 H, m, 1′-H), 2.33 (1 H, ddq, *J* 14.0, 7.5, 1.0, 1′-H), 2.86 (2 H, m, 2-CH_2), 3.21 (1 H, d, *J* 2, OH), 3.75–3.92 (2 H, m, 4′-CH_2), 4.01 (1 H, m, 2′-H) and 5.59 (1 H, tt, *J* 4, 1, 5-H); *m/z* (CI, NH_3) 303 (MH^+, 2.1%) and 285 (100).

6-[4-tert-*Butyldimethylsiloxy*-2-(2-*trimethylsilylethoxy*)*methoxybutyl*]-3,4-*dihydro*-2H-*thiopyran* **44**.—Diisopropylethylamine (3.76 cm^3, 21.60 mmol) and 2-(trimethylsilyl)ethoxymethyl chloride (2.55 cm^3, 14.42 mmol) were added to a solution of the alcohol **43** (2.18 g, 7.21 mmol) in dichloromethane (10 cm^3), at 0 °C. After being stirred for 2 h at ambient temperature, the reaction was quenched with saturated aqueous ammonium chloride (50 cm^3). Ether extraction and chromatography (light petroleum–ether) gave the *title compound* **44** as a colourless oil (3.00 g, 96%); ν_{max}/cm^{-1} 1250, 1099, 1030, 939, 836, 776 and 694; δ_H(300 MHz; $CDCl_3$) 0.02 (9 H, s, $SiMe_3$), 0.07 (6 H, s, $SiMe_2$), 0.81–1.01 (2 H, m, CH_2Si), 0.90 (9 H, s, Bu^t), 1.62–1.73 and 1.73–1.86 (each 1 H, m, 3′-H), 1.87–1.96 (2 H, m, 3-CH_2), 2.10–2.19 (2 H, m, 4-CH_2), 2.23 and 2.41 (each 1 H, dd, *J* 14.0, 6.5, 1′-H), 2.82–2.88 (2 H, m, 2-CH_2), 3.57–3.78 (4 H, m, 4′-CH_2 and O$CH_2CH_2SiMe_3$), 3.91 (1 H, m, 2′-H), 4.69 and 4.75 (each 1 H, d, *J* 7.0, OC*H*HO) and 5.57 (1 H, t, *J* 4.1, 5-H); *m/z* (CI, NH_3) 450 (MNH_4^+, 0.2%) and 433 (MH^+, 0.5).

6-[4-*Hydroxy*-2-(2-*trimethylsilylethoxy*)*methoxybutyl*]-3,4-*dihydro*-2H-*thiopyran* **45**.—Tetrabutylammonium fluoride (1.0 mol dm^{-3} in THF; 17.4 cm^3, 17.4 mmol) was added dropwise to a stirred solution of the silyl ether **44** (3.0 g, 6.94 mmol) in THF (15 cm^3) at 0 °C. The reaction mixture was stirred for 2.5 h at ambient temperature before being quenched with saturated aqueous ammonium chloride (50 cm^3). Extraction into ethyl acetate and chromatography [ethyl acetate–light petroleum] afforded the *title compound* **45** as a pale yellow oil (2.32 g, 100%); ν_{max}/cm^{-1} 3431, 1249, 1154, 1103, 1027, 860 and 836; δ_H(300 MHz; $CDCl_3$) 0.03 (9 H, s, $SiMe_3$), 0.97 (2 H, m, CH_2SiMe_3), 1.63 (1 H, m, 3′-H), 1.81–1.99 (3 H, m, 3-CH_2 and 3′-H), 2.09–2.19 (2 H, m, 4-CH_2), 2.22 and 2.43 (each 1 H, dd, *J* 14.5, 6.5, 1′-H), 2.66 (1 H, t, *J* 6.2, OH), 2.79–2.96 (2 H, m, 2-CH_2), 3.58 (1 H, td, *J* 9.5, 7.0, OC*H*HCH_2SiMe_3), 3.66–3.87 (3 H, m, 4′-CH_2 and OCH*H*CH_2SiMe_3), 3.99 (1 H, m, 2′-H), 4.71 and 4.78 (each 1 H, d, *J* 6.5, OC*H*HO) and 5.58 (1 H, t, *J* 4.1, 5-H); *m/z* (CI, NH_3) 336 (MNH_4^+, 2.0%), 319 (MH^+ + 1, 6.6) and 201 (100).

6-[4-*Acetylthio*-2-(2-*trimethylsilylethoxy*)*methoxybutyl*]-3,4-*dihydro*-2H-*thiopyran* **46**.—Diisopropyl azodicarboxylate (2.87 cm^3, 14.58 mmol) was added dropwise to a stirred solution of triphenylphosphine (3.82 g, 14.58 mmol) in THF (35 cm^3) at 0 °C. After 0.5 h a solution of alcohol **45** (2.32 g, 7.29 mmol) and thiolacetic acid (1.04 cm^3, 14.58 mmol) in THF (15 cm^3) was added. After 1 h at 0 °C and 1 h at ambient temperature, the reaction mixture was concentrated under reduced pressure, dissolved in light petroleum, filtered and the filtrate concentrated. Chromatography of the residue [light petroleum–ether (9:1)] gave the *title thioester* **46** as a colourless oil (2.34 g, 90%); ν_{max}/cm^{-1} 1694, 1436, 1354, 1249, 1135, 1103, 1027, 938, 860 and 837; δ_H(300 MHz; $CDCl_3$) 0.04 (9 H, s, $SiMe_3$), 0.96 (2 H, t, *J* 8.0, CH_2Si), 1.68–1.90 (2 H, m, 3′-CH_2), 1.90–2.00 (2 H, m, 3-CH_2), 2.10–2.22 (2 H, m, 4-CH_2), 2.14 (1 H, dd, *J* 15.0, 7.0, 1′-H), 2.32 (3 H, s, COMe), 2.53 (1 H, dd, *J* 15.0, 7.0, 1′-H), 2.80–2.89 (2 H, m, 2-CH_2), 2.87–2.98 and 2.98–3.11 (each 1 H, m, 4′-H), 3.67 (2 H, m, OCH_2CH_2Si), 3.85 (1 H, m, 2′-H), 4.69 and 4.77 (each 1 H, d, *J* 7.0, OC*H*HO) and 5.59 (1 H, t, *J* 4.1, 5-H); *m*/*z* (CI, NH_3) 394 (MNH_4^+, 10.0%), 371 (MH^+, 2.1) and 259 (100).

1,7-*Dithiaspiro*[5.5]*undecan*-4-*ols* **48** *and* **50**.—A solution of the thioester **46** (7.89 g, 20.98 mmol) in ether (50 cm^3) was added dropwise to a stirred suspension of lithium aluminium hydride (1.59 g, 41.97 mmol) in ether (30 cm^3) at 0 °C. After 1 h the reaction mixture was quenched by the sequential dropwise addition of water (1.6 cm^3), 15% aqueous sodium hydroxide solution (1.6 cm^3) and water (4.8 cm^3). After being vigorously stirred at ambient temperature for a further 0.5 h the reaction mixture was filtered through Celite and the filter-cake washed with ethyl acetate (100 cm^3). The combined filtrates were concentrated under reduced pressure to give the thiol **47** (6.55 g) which was used immediately without further purification; δ_H(300 MHz; $CDCl_3$) 0.06 (9 H, s, $SiMe_3$), 0.98 (2 H, t, *J* 7.5, CH_2Si), 1.48 (1 H, t, *J* 7.5, SH), 1.78–1.90 (2 H, m, 3′-CH_2), 1.90–2.02 (2 H, m, 3-CH_2), 2.12–2.22 (3 H, m, 4-CH_2 and 1′-H), 2.44 (1 H, dd, *J* 14.0, 7.0, 1′-H), 2.67 (2 H, m, 4′-CH_2), 2.82–2.91 (2 H, m, 2-CH_2), 3.61 and 3.71 (each 1 H, m, OC*H*HCH_2Si), 3.92 (1 H, quint, *J* 6.0, 2′-H), 4.71 and 4.79 (each 1 H, d, *J* 7.0, OC*H*O) and 5.59 (1 H, t, *J* 4.0, 5-H).

Aqueous hydrofluoric acid (*ca.* 25%; 40 cm^3) was added to a stirred solution of the thiol **47** (6.55 g) in acetonitrile (100 cm^3), and the reaction mixture was stirred under an atmosphere of argon for 5 h. The reaction was quenched by the slow addition (**CARE**) of solid sodium carbonate until effervescence ceased. The reaction mixture was then concentrated under reduced pressure to *ca.* 50 cm^3. Extraction into ethyl acetate and chromatography [light petroleum–ethyl acetate (70:30)] gave a mixture of the *spiroacetals* **48** and **50** [3.25 g, 76%, ratio 95:5 (^{1}H NMR)] which were partially separated by chromatography.

The less polar diastereoisomer **50** was a crystalline solid, m.p. 84.5–85.5 °C (Found: M^+, 204.0642. $C_9H_{16}OS_2$ requires *M*, 204.0643); ν_{max}/cm^{-1} 3314, 1434, 1251, 1048 and 931; δ_H(300 MHz; C_6D_6) 1.23–1.9 (9 H, m), 2.03–2.39 (4 H, m), 2.76–2.95 (2 H, m) and 3.78 (1 H, m, 4-H); *m*/*z* EI 204 (M^+, 63%) and 143 (100%). The more polar diastereoisomer **48** was also a crystalline solid, m.p. 97–98 °C (Found: M^+, 204.0645. $C_9H_{16}OS_2$ requires *M*, 204.0643); ν_{max}/cm^{-1} 3298, 1427, 1251, 1060, 1042, 1018 and 931; δ_H(300 MHz; $CDCl_3$) 1.41–1.65 (3 H, m), 1.67–2.15 (7 H, m), 2.25–2.47 (3 H, m), 3.0–3.17 (2 H, m) and 3.88–4.05 (1 H, m, 4-H); *m*/*z* (EI) 204 (M^+, 89%) and 143 (100%).

p-Nitrobenzoyl chloride (81.9 mg, 0.441 mmol) was added to a stirred solution of triethylamine (123 mm^3, 0.882 mmol), 4-dimethylaminopyridine (1 mg) and the spiroacetal **48** (45 mg, 0.221 mmol) in dichloromethane (1 cm^3). After 5 h a further portion of *p*-nitrobenzoyl chloride (81.9 mg, 0.441 mmol) and triethylamine (123 mm^3, 0.882 mmol) was added. The reaction mixture was stirred for 10 h before being partitioned between water (5 cm^3) and ether (10 cm^3). Ether extraction and chromatography [light petroleum–ether (9:1)] gave the p-*nitrobenzoate* **49** (74 mg, 94%) as pale yellow crystals, m.p. 145–147 °C (Found: M^+, 353.0770. $C_{16}H_{19}NO_4S_2$ requires *M*, 353.0755); ν_{max}/cm^{-1} 1723, 1607, 1527, 1275, 1104 and 985; δ_H(300 MHz; $CDCl_3$) 1.53–1.89 (4 H, m), 1.9–2.18 (4 H, m), 2.16 (1 H, dt, *J* 14.3, 3.5), 2.36–2.56 (3 H, m), 2.95 and 3.15 (each 1 H, m), 5.29–5.42 (1 H, m) and 8.21 and 8.27 (each 2 H, d, *J* 8, ArH); *m*/*z* EI 353 (M^+, 51%).

1,7-*Dithiaspiro*[5.5]*undecan*-4-*one* **51**.—Tetrapropylammonium perruthenate (95 mg, 0.27 mmol) was added to a mixture of the spiroacetal **48** (1.1 g, 5.39 mmol), *N*-methylmorpholine *N*-oxide (1.09 g, 8.09 mmol) and activated 3 Å molecular sieves (2.7 g) in dichloromethane (10 cm^3) and acetonitrile (1 cm^3). After 3 h, silica, (*ca.* 200 mg) was added to the reaction mixture which was then stirred for a further 0.5 h and filtered through a plug of silica. The silica was washed with ethyl acetate (100 cm^3) and the combined filtrates were concentrated under reduced pressure. Chromatography of the residue [light petroleum–ethyl acetate (3:1)] gave the *title compound* **51** as a colourless oil (850 mg, 78%) (Found: M^+, 202.0485. $C_9H_{14}OS_2$ requires *M*, 202.0486); ν_{max}/cm^{-1} 1712, 1419, 1320, 1284, 1242, 1173 and 932; δ_H(300 MHz; C_6D_6) 1.2–1.9 (6 H, m), 1.97–2.17 (2 H, m), 2.24 (1 H, dt, *J* 15, 4.5), 2.32–2.51 (2 H, m), 2.62–2.83 (2 H, m) and 2.95–3.13 (1 H, m); *m*/*z* (EI) 202 (M^+, 100%).

(2S,4S)-4-(tert-*Butyldiphenylsilyloxy*)-1,2-*isopropylidenedioxyhept*-6-*ene* **55**.—*tert*-Butyldiphenylsilyl chloride (9.97 cm^3, 30.65 mmol) was added to a stirred solution of the alcohol **54**[26] (3.8 g, 20.43 mmol), imidazole (2.78 g, 40.86 mmol) and 4-dimethylaminopyridine (250 mg, 2.05 mmol) in DMF (10 cm^3) at 0 °C. The reaction mixture was stirred at ambient temperature for 18 h and then quenched with saturated aqueous ammonium chloride. Ether extraction and chromatography [light petroleum–ether (9:1)] gave the *title compound* **55** as a colourless oil (8.11 g, 94%), $[\alpha]^{17}$ +22.7 (*c* 0.97, $CHCl_3$); ν_{max}/cm^{-1} 3072, 1217, 1160, 1110, 1062, 740 and 704; δ_H(300 MHz; $CDCl_3$) 1.09 (9 H, s, $SiBu^t$), 1.31 (6 H, s, CMe_2), 1.66 and 1.88 (each 1 H, dt, *J* 14.0, 6.0, 3-H), 2.12–2.28 and 2.34 (each 1 H, m, 5-H), 3.33 (1 H, t, *J* 7.9, 1-H), 3.81 (1 H, dd, *J* 7.9, 5.9, 1-H), 3.89 (1 H, m, 2-H), 4.19 (1 H, quint, *J* 6.8, 4-H), 4.95 and 5.00 (each 1 H, m, 7-H), 5.75 (1 H, ddt, *J* 16.9, 10.1, 7.1, 6-H), 7.34–7.51 (6 H, m, ArH) and 7.66–7.79 (4 H, m, ArH); *m*/*z* (CI, NH_3) 442 (MNH_4^+, 17.1%), 425 (MH^+, 37.3) and 347 (100).

(2S,4S)-4-(tert-*Butyldiphenylsilyloxy*)-1,2-*epoxyhept*-6-*ene* **56**.—A solution of the silyl ether **55** (2.0 g, 4.72 mmol) in 80% aqueous acetic acid (50 cm^3) was stirred at ambient temperature for 8 h. The reaction mixture was concentrated under reduced pressure. Chromatography of the residue [light petroleum–ethyl acetate (1:1)] gave (2*S*,4*S*)-4-(*tert*-butyldiphenylsiloxy)-hept-6-ene-1,2-diol (1.8 g, 100%); $[\alpha]^{17}$ +37.5 (*c* 1.62, $CHCl_3$); ν_{max}/cm^{-1} 3385, 3072, 1641, 1428, 1112, 915, 823 and 703; δ_H(300 MHz; $CDCl_3$) 1.10 (9 H, s, $SiBu^t$), 1.58–1.72 (2 H, m, 3-CH_2), 2.11–2.30 (2 H, m, 5-CH_2), 2.52 and 3.12 (each 1 H, br s, OH), 3.35 and 3.52 (each 1 H, m, 1-H), 3.89 (1 H, m, 2-H), 4.04 (1 H, quint, *J* 5.7, 4-H), 4.85 (1 H, dd, *J* 16.5, 1, 7-H), 4.96 (1 H, dd, *J* 9.8, 1, 7-H), 5.62 (1 H, ddt, *J* 16.5, 9.8, 7.5, 6-H), 7.34–7.51 (6 H, m, ArH) and 7.68–7.79 (4 H, m, ArH).

A solution of toluene-*p*-sulfonyl chloride (2.13 g, 11.17 mmol) in pyridine (15 cm^3) was added dropwise to a stirred solution of the diol (858 mg, 2.23 mmol) and 4-*N*,*N*-dimethylaminopyridine (27 mg, 0.22 mmol) in pyridine (15 cm^3) at 0 °C. The reaction mixture was allowed to warm slowly to ambient temperature

and was stirred for 6 h. Ether extraction and chromatography [light petroleum–ether (1:1)] afforded the primary monotosylate (1.15 g, 96%), $[\alpha]^{17}$ +29.9 (*c* 0.83, $CHCl_3$); ν_{max}/cm^{-1} 3543, 3071, 1599, 1362, 1177, 1110, 976, 821 and 705; δ_H(300 MHz; $CDCl_3$) 1.01 (9 H, s, SiBu^t), 1.56–1.68 (2 H, m, 3-CH_2), 2.05–2.25 (2 H, m, 5-CH_2), 2.45 (3 H, s, Me), 2.67 (1 H, d, *J* 2.8, OH), 3.78 (1 H, dd, *J* 10.0, 1.6, 1-H), 3.87–3.98 (2 H, m, 1-H and 4-H), 3.98–4.08 (1 H, m, 2-H), 4.82 (1 H, dd, *J* 17.3, 1.5, 7-H), 4.93 (1 H, dd, *J* 10.0, 1.5, 7-H), 5.55 (1 H, ddt, *J* 17.3, 9.8, 7.2, 6-H), 7.34 (2 H, d, *J* 7.5, ArH), 7.36–7.49 (6 H, m, ArH), 7.68 (4 H, d, *J* 7.5, ArH) and 7.78 (2 H, d, *J* 7.5, ArH); *m/z* (CI, NH_3) 461 (37.3%).

Anhydrous potassium carbonate (890 mg, 6.44 mmol) was added to a solution of the monotosylate (1.65 g, 3.07 mmol) in methanol (20 cm^3). The resultant slurry was stirred at ambient temperature for 2 h before being diluted with ether (50 cm^3) and filtered. Ether extraction and chromatography [light petroleum–ether (8:1)] afforded the *title epoxide* **56** as a colourless oil (920 mg, 82%); $[\alpha]^{17}$ +12.0 (*c* 1.29, $CHCl_3$); ν_{max}/cm^{-1} 3072, 3050, 1641, 1590, 1428, 1111, 824, 740 and 704; δ_H(300 MHz; $CDCl_3$) 1.09 (9 H, s, SiBu^t), 1.63 and 1.73 (each 1 H, dt, *J* 14.0, 5.7, 3-H), 2.20–2.50 (3 H, m, 1-H and 5-CH_2), 2.65 (1 H, t, *J* 4.5, 1-H), 3.04 (1 H, m, 2-H), 3.98 (1 H, m, 4-H), 4.90–5.03 (2 H, m, 7-CH_2), 5.73 (1 H, ddt, *J* 17.5, 10.0, 7.0, 6-H), 7.35–7.49 (6 H, m, ArH) and 7.66–7.73 (4 H, m, ArH); *m/z* (CI, NH_3) 384 (MNH^+, 15.1%).

(2′S,4′S)-6-(4-tert-*Butyldiphenylsilyloxy*-2-*hydroxyhept*-6-*enyl*)-3,4-*dihydro*-2H-*thiopyran* **57**.—Freshly distilled boron trifluoride–diethyl ether (296 mm^3, 2.40 mmol) was added to a stirred solution of the epoxide **56** (800 mg, 2.19 mmol) in THF (16 cm^3) at −78 °C. A cooled solution (−78 °C) of lithiated dihydrothiopyran **25**[23] (6.57 mmol) in THF (8 cm^3) was added. After 10 min the reaction was quenched by the addition of saturated aqueous sodium hydrogen carbonate (10 cm^3). Ether extraction and chromatography [light petroleum–ether (5:1)] gave the *title compound* **57** as a colourless oil (871 mg, 86%), $[\alpha]^{19}$ +0.31 (*c* 1.30, $CHCl_3$); ν_{max}/cm^{-1} 3450, 3080, 1650, 1438, 1107, 1095, 1075, 752 and 708; δ_H(300 MHz; C_6D_6) 1.28 (9 H, s, SiBu^t), 1.52–1.64 (2 H, m, 3-CH_2), 1.79–1.92 (4 H, m, 4-CH_2 and 3′-CH_2), 2.05 (1 H, br s, OH), 2.15–2.58 (6 H, m, 2-CH_2, 1′-CH_2 and 5′-CH_2), 4.21 (1 H, m, 2′-H), 4.35 (1 H, quint, *J* 5.8, 4′-H), 4.99–5.11 (2 H, m, 7′-CH_2), 5.42 (1 H, t, *J* 4.3, 5-H), 5.96 (1 H, ddt, *J* 17.4, 10.8, 7.3, 6′-H), 7.35–7.48 (6 H, m, ArH) and 7.85–7.97 (4 H, m, ArH); *m/z* (CI, NH_3) 467 (MH^+, 30.3%).

(2′S,4′S)-6-[4-tert-*Butyldiphenylsilyloxy*-2-(2-*trimethylsilylethoxy*)*methoxyhept*-6-*enyl*]-3,4-*dihydro*-2H-*thiopyran* **58**.—To a stirred solution of the alcohol **57** (871 mg, 1.87 mmol) and diisopropylethylamine (972 mm^3, 5.61 mmol) in dichloromethane (5 cm^3), at 0 °C, was added 2-(trimethylsilyl)ethoxymethyl chloride (434 mm^3, 3.74 mmol). After being stirred at ambient temperature for 14 h the reaction mixture was quenched with saturated aqueous ammonium chloride (5 cm^3). Ether extraction and chromatography [light petroleum–ether (15:1)] gave the *title compound* **58** as a colourless oil (1.08 g, 97%), $[\alpha]^{17}$ −3.1 (*c* 0.91, $CHCl_3$); ν_{max}/cm^{-1} 3072, 1640, 1590, 1428, 1249, 1108, 1055, 1028, 836 and 703; δ_H(300 MHz; C_6D_6) 0.07 (9 H, s, $SiMe_3$), 0.99 (2 H, t, *J* 7.9, CH_2Si), 1.30 (9 H, s, SiBu^t), 1.59–1.70 (2 H, m, 3-CH_2), 1.86–1.97 (2 H, m, 4-CH_2), 2.01–2.19 (2 H, m, 3′-CH_2), 2.31 (1 H, dd, *J* 13.5, 6.0, 1′-H), 2.42–2.68 (5 H, m, 2-CH_2, 1′-H and 5′-CH_2), 3.65 (2 H, m, OCH_2CH_2Si), 4.18 (1 H, quint, *J* 6.2, 2′-H), 4.35 (1 H, quint, *J* 5.6, 4′-H), 4.68 and 4.79 (each 1 H, d, *J* 6.8, OC*H*HO), 5.14 (2 H, m, 7′-CH_2), 5.48 (1 H, t, *J* 3.9, 5-H), 6.09 (1 H, m, 6′-H), 7.27–7.39 (6 H, m, ArH) and 7.78–7.89 (4 H, m, ArH); *m/z* (CI, NH_3) 479 (11.3%).

(2′S,4′S)-6-[2-(2-*Trimethylsilylethoxy*)*methoxy*-4-*hydroxyhept*-6-*enyl*]-3,4-*dihydro*-2H-*thiopyran* **59**.—Tetrabutylammonium fluoride (1.0 mol dm^{-3} in THF; 4.98 cm^3, 4.98 mmol) was added to a stirred solution of the silyl ether **58** (990 mg, 1.66 mmol) in THF (3 cm^3) at 0 °C. After being stirred at ambient temperature for 14 h the reaction mixture was quenched with saturated aqueous ammonium chloride (10 cm^3). Ether extraction and chromatography [light petroleum–ether (3:1)] afforded the *title compound* **59** as a colourless oil (535 mg, 91%), $[\alpha]^{19}$ 39.1 (*c* 1.65, $CHCl_3$); ν_{max}/cm^{-1} 3465, 3072, 1640, 1420, 1249, 1110, 1056, 1025, 860 and 836; δ_H(200 MHz; C_6D_6) 0.01 (9 H, s, $SiMe_3$), 0.87–1.05 (2 H, m, CH_2Si), 1.48–1.63 (2 H, m, 3-CH_2), 1.63–1.90 (4 H, m, 4-CH_2 and 3′-CH_2), 2.18–2.36 (3 H, m, 1′-H and 5′-CH_2), 2.41–2.51 (2 H, m, 2-CH_2), 2.58 (1 H, ddd, *J* 14.8, 6.3, 1.1, 1′-H), 3.10 (1 H, br s, OH), 3.64 (2 H, m, OCH_2CH_2Si), 3.94 (1 H, br quint, *J* 6.0, 2′-H), 4.18 (1 H, m, 4′-H), 4.62 and 4.76 (each 1 H, d, *J* 6.5, OC*H*HO), 5.00–5.14 (2 H, m, 7′-CH_2), 5.44 (1 H, t, *J* 4.4, 5-H) and 5.98 (1 H, ddt, *J* 17.4, 10.1, 7.2, 6′-H); *m/z* (CI, NH_3) 376 (MNH_4^+, 20.9%) and 359 (MH^+, 14.5).

(2′S,4′R)-6-[4-*Acetylthio*-2-(2-*trimethylsilylethoxy*)*methoxyhept*-6-*enyl*]-3,4-*dihydro*-2H-*thiopyran* **60**.—Diisopropyl azodicarboxylate (110 mm^3, 0.560 mmol) was added to a stirred solution of triphenylphosphine (147 mg, 0.560 mmol) in THF at 0 °C. After 0.5 h a solution of the alcohol **59** (50 mg, 0.140 mmol) and thioacetic acid (40 mm^3, 0.560 mmol) in THF (0.65 cm^3) was added. The reaction mixture was stirred for a further 12 h and allowed to warm slowly to ambient temperature when it was concentrated under reduced pressure. Trituration of the residue in hexane, filtration, concentration of the filtrate, and chromatography of the residue [light petroleum–ether (15:1)] afforded the *title compound* **60** as a colourless oil (39 mg, 67%); ν_{max}/cm^{-1} 1691, 1436, 1249, 1117 1029, 919, 860 and 836; δ_H(300 MHz; C_6D_6) 0.10 (9 H, s, $SiMe_3$), 1.08 (2 H, m, CH_2Si), 1.59–1.69 (2 H, m, 3-CH_2), 1.88–2.01 (4 H, m, 4-CH_2 and 3′-CH_2), 1.95 (3 H, s, Me), 2.37 (1 H, dd, *J* 14.2, 7.9, 1′-H), 2.44–2.63 (4 H, m, 2-CH_2 and 5′-CH_2), 2.82 (1 H, m, 1′-H), 3.82 (2 H, m, OCH_2CH_2Si), 4.17 (1 H, quint, *J* 6.8, 4′-H), 4.27 (1 H, m, 2′-H), 4.86 and 4.93 (each 1 H, d, *J* 7.0, OC*H*HO), 5.07–5.19 (2 H, m, 7′-CH_2), 5.54 (1 H, t, *J* 4.4, 5-H) and 5.93 (1 H, ddt, *J* 17.2, 10.0, 7.1, 6′-H).

2-*Allyl*-1,7-*dithiaspiro*[5.5]*undecan*-4-*ols* **62** *and* **63**.—Lithium aluminium hydride (50.8 mg, 1.337 mmol) was added to a stirred solution of the thioester **60** (139 mg, 0.334 mmol) in ether (10 cm^3) at 0 °C. After 0.5 h the reaction was quenched by the sequential addition of water (51 mm^3), 15% aqueous sodium hydroxide (51 mm^3) and water (153 mm^3), and the mixture stirred at ambient temperature for 1 h. The mixture was filtered through Celite and the filter-cake washed with ethyl acetate (20 cm^3). The filtrate was concentrated under reduced pressure to afford the thiol **61** which was immediately dissolved in acetonitrile (6 cm^3). Aqueous hydrofluoric acid (48%; 0.4 cm^3) was added dropwise, and the reaction mixture was stirred at ambient temperature for 14 h. It was then quenched by the dropwise addition of saturated aqueous sodium hydrogen carbonate. Ether extraction and chromatography [light petroleum–ether (2:1)] afforded the *title compounds* (73%).

The less polar diastereoisomer **62** (55 mg) was a colourless oil $[\alpha]^{17}$ +290.1 (*c* 1.03, $CHCl_3$) (Found: M^+, 244.0967. $C_{12}H_{20}OS_2$ requires *M*, 244.0956); ν_{max}/cm^{-1} 3338, 1640, 1438, 1250, 1041, 1001, 916 and 670; δ_H(500 MHz; C_6D_6) 1.2–1.53 (4 H, m), 1.63–2.02 (5 H, m), 2.11–2.4 (5 H, m), 3.03–3.1 and 3.2–3.3 (each 1 H, m), 4.00 (1 H, m, 4-H), 5.02–5.12 (2 H, m, 3′-CH_2) and 5.81 (1 H, m, 2′-H); *m/z* (CI, NH_3) 245 (MH^+, 100%).

The more polar diastereoisomer **63** (5 mg) was an oil, $[\alpha]^{21}$ −13.6 (*c* 0.5, $CHCl_3$) (Found: M^+, 244.0954. $C_{12}H_{20}OS_2$

requires *M*, 244.0956); ν_{max}/cm^{-1} 3385, 3085, 1640, 1437, 1046, 996 and 919; δ_H(300 MHz) 1.2 (1 H, q, *J* 11.2), 1.31–1.7 (4 H, m), 1.76–2.26 (9 H, m), 2.34–2.46 and 3.0–3.15 (each 1 H, m), 3.49 (1 H, m, 4-H), 4.96–5.1 (2 H, m, 3′-CH_2) and 5.65–5.83 (1 H, m, 2′-H); *m*/*z* (CI, NH_3) 262 (MNH_4^+, 63%) and 245 (MH^+, 100%).

1,4-*Dioxa*-8-*thiaspiro*[4.5]*dec*-6-*ene* **65**.—A mixture of thiinone **64**[11,12] (992 mg, 8.70 mmol), ethylene glycol (5.40 g, 87.0 mmol) and pyridinium toluene-*p*-sulfonate (219 mg, 0.87 mmol) in benzene (20 cm^3) was heated at reflux under Dean–Stark conditions for 14 h. Ether extraction and chromatography of the residue [light petroleum–ether (5:1)] gave the *title compound* **65** as a colourless oil (830 mg, 60%); ν_{max}/cm^{-1} 1603, 1169, 1104 and 1023; δ_H(300 MHz) 2.10 (2 H, m, 1-CH_2), 3.02 (2 H, m, 2-CH_2), 4.01 (4 H, m, 8- and 9-CH_2) and 5.68 and 6.34 (each 1 H, d, *J* 9, 5-H and 6-H); *m*/*z* (EI) 158 (M^+, 10%) and 130 ($M^+ - 28$, 29%).

7-(4-tert-*Butyldimethylsiloxy*-2-*hydroxybutyl*)-1,4-*dioxa*-8-*thiaspiro*[4.5]*dec*-6-*ene* **66**.—*sec*-Butyllithium (11.62 mmol) was added dropwise to a solution of the ketal **65** (1.79 g, 11.34 mmol) in THF (18 cm^3) at −78 °C. After 1 h, the reaction mixture was added to a solution of boron trifluoride–diethyl ether (1.40 cm^3, 11.34 mmol) in THF (25 cm^3) at −78 °C. A solution of epoxide **14**[14] (1.15 g, 5.67 mmol) in THF (10 cm^3) was then added to the reaction mixture which was stirred at −78 °C for a further 0.5 h before being quenched with saturated aqueous sodium hydrogen carbonate (50 cm^3). Ether extraction and chromatography [light petroleum–ethyl acetate (1:1)] gave the *title compound* **66** (1.79 g, 88%) as a colourless oil (Found: $M^+ - C_4H_9$, 303.1090. $C_{13}H_{23}O_4SSi$ requires *M*, 303.1086); ν_{max}/cm^{-1} 3473, 1629, 1256, 1089, 837 and 777; δ_H(200 MHz; C_6D_6) 0.19 (6 H, s, $SiMe_2$), 1.10 (9 H, s, SiBu^t), 1.72–1.87 (2 H, m, 3′-CH_2), 2.01–2.11 (2 H, m, 10-CH_2), 2.47 (1 H, ddd, *J* 13.6, 5.6, 1, 1′-H), 2.63 (1 H, ddd, *J* 13.6, 7.4, 1, 1′-H), 2.83–2.92 (2 H, m, 9-CH_2), 3.02 (1 H, s, OH), 3.54–3.93 (6 H, m, 2-CH_2, 3-CH_2, and 4′-CH_2), 4.70 (1 H, m, 2′-H) and 5.89 (1 H, s, 6-H); *m*/*z* (CI, NH_3) 361 ($M^+ + 1$, 1.8%) and 189 (92).

7-[4-tert-*Butyldimethylsilyloxy*-2-(2-*trimethylsilylethoxy*)-*methoxybutyl*]-1,4-*dioxa*-8-*thiaspiro*[4.5]*dec*-6-*ene* **67**.—2-(Trimethylsilylethoxy)methyl chloride (784 mm^3, 4.43 mmol) was added to a stirred solution of alcohol **66** (797 mg, 2.21 mmol) and diisopropylethylamine (1.16 mm^3, 6.64 mmol) in dichloromethane (5 cm^3) at 0 °C. After being stirred at ambient temperature for 14 h the reaction mixture was quenched with saturated aqueous ammonium chloride (5 cm^3) and diluted with ether (50 cm^3). Ether extraction and chromatography [light petroleum–ether (2:1)] afforded the *title compound* **67** (1.09 g, 100%), as a pale yellow oil (Found: M^+, 491.2702. $C_{23}H_{47}O_5SSi_2$ requires *M*, 491.2683); ν_{max}/cm^{-1} 1629, 1250, 1093, 1028, 836 and 776; δ_H(300 MHz; C_6D_6) 0.10 (9 H, s, $SiMe_3$), 0.18 (6 H, s, $SiMe_2$), 1.0–1.12 (2 H, m, CH_2Si), 1.08 (9 H, s, Bu^t), 1.84–2.05 (4 H, m, 10-CH_2 and 3′-CH_2), 2.47 (1 H, dd, *J* 14.1, 6.3, 1′-H), 2.72 (1 H, dd, *J* 14.1, 6.8, 1′-H), 2.75–2.82 (2 H, m, 9-CH_2), 3.46–3.58 and 3.58–3.68 (each 2 H, m, 2-CH_2 and 3-CH_2), 3.73–3.93 (4 H, m, 4′-CH_2 and OCH_2CH_2Si), 4.28 (1 H, m, 2′-H), 4.88 (2 H, s, OCH_2O) and 5.84 (1 H, s, 6-H); *m*/*z* (CI, NH_3) 491 ($M^+ + 1$, 36.2%).

7-[4-*Hydroxy*-2-(2-*trimethylsilylethoxy*)*methoxybutyl*]-1,4-*dioxa*-8-*thiaspiro*[4.5]*dec*-6-*ene* **68**.—Tetrabutylammonium fluoride (1.0 mol dm^{-3} in THF; 0.42 cm^3, 4.98 mmol) was added to a stirred solution of the silyl ether **67** (104 mg, 0.212 mmol) in THF (0.5 cm^3) at 0 °C. After being stirred at ambient temperature for 14 h, the reaction mixture was quenched with saturated aqueous ammonium chloride (5 cm^3). The mixture was extracted with ethyl acetate, the extract concentrated and the residue chromatographed [light petroleum–ethyl acetate (1:5)] to afford the *title compound* **68** (76 mg, 95%) as a colourless oil (Found: M^+, 377.1814. $C_{17}H_{33}O_5SSi$ requires *M*, 377.1818); ν_{max}/cm^{-1} 3466, 1629, 1428, 1249, 1169, 1090, 1057, 1026, 861 and 837; δ_H(300 MHz; C_6D_6) 0.05 (9 H, s, $SiMe_3$), 1.00 (2 H, t, *J* 7.6, CH_2Si), 1.61–1.75 and 1.78–1.91 (each 1 H, m, 3′-H), 1.93 (2 H, m, 10-CH_2), 2.31 (1 H, dd, *J* 14, 6.3, 1′-H), 2.48–2.64 (1 H, br s, OH), 2.58 (1 H, dd, *J* 14, 6.8, 1′-H), 2.78 (2 H, m, 9-CH_2), 3.49–3.90 (8 H, m, 2-CH_2, 3-CH_2, 4′-CH_2, OCH_2CH_2-Si), 4.20 (1 H, m, 2′-H) 4.73 and 4.78 (each 1 H, d, *J* 7.2, OC*H*HO) and 5.73 (1 H, s, 6-H); *m*/*z* (CI, NH_3) 377 (MH^+, 57%).

7-[4-*Acetylthio*-2-(2-*trimethylsilylethoxy*)*methoxybutyl*]-1,4-*dioxa*-8-*thiaspiro*[4.5]*dec*-6-*ene* **69**.—Diisopropyl azodicarboxylate (80 mm^3, 0.404 mmol) was added dropwise to a cooled solution of triphenylphosphine (106 mg, 14.58 μmol) in THF (1.0 cm^3). After 0.5 h, a solution of alcohol **68** (76 mg, 0.202 mmol) and thioacetic acid (29 mm^3, 0.404 mmol) in THF (1.5 cm^3) was added. After being stirred for 1 h at 0 °C and for 1 h at ambient temperature, the reaction mixture was concentrated under reduced pressure. Chromatography of the residue [light petroleum–ether (2:1)] gave the *title compound* **69** (59 mg, 68%) as a colourless oil (Found: M^+, 435.1711. $C_{19}H_{35}O_5S_2Si$ requires *M*, 435.1695); ν_{max}/cm^{-1} 1693, 1629, 1244, 1116, 1026, 861 and 834; δ_H(300 MHz; C_6D_6) 0.08 (9 H, s, $SiMe_3$), 1.06 (2 H, t, *J* 8.7, CH_2Si), 1.80–2.05 (4 H, m, 10-CH_2 and 3′-CH_2), 1.95 (3 H, s, SCOMe), 2.31 and 2.59 (each 1 H, dd, *J* 14.2, 6.3, 1′-H), 2.77 (2 H, m, 9-CH_2), 2.98–3.11 and 3.14–3.26 (each 1 H, m, 4′-H), 3.48–3.59 and 3.59–3.68 (each 2 H, m, 2-CH_2 and 3-CH_2), 3.69 and 3.82 (each 1 H, q, *J* 8.7, OCH*H*CH_2Si), 4.09 (1 H, m, 2′-H), 4.75 and 4.83 (each 1 H, d, *J* 6.8, OC*H*HO) and 5.79 (1 H, s, 6-H); *m*/*z* (CI, NH_3) 435 (MH^+, 100%).

10-*Hydroxy*-1,7-*dithiaspiro*[5.5]*undecan*-4-*one* **71**.—Lithium aluminium hydride (5.0 mg, 0.129 mmol) was added to a stirred solution of the thioester **69** (28 mg, 64.3 μmol) in ether (1 cm^3) at 0 °C. After being stirred for 1 h at 0 °C, the reaction mixture was diluted with ether (2 cm^3) and quenched by the addition of water (5 cm^3), aqueous sodium hydroxide (15%; 5 cm^3) and water (15 cm^3). After being stirred for 1 h at ambient temperature, the reaction mixture was filtered through Celite and the filter-cake washed with ethyl acetate (20 cm^3). The filtrate was concentrated under reduced pressure to afford the thiol **70** which was immediately dissolved in acetonitrile (1.0 cm^3). Aqueous hydrofluoric acid (1 drop, 48%) was added, and the reaction mixture stirred at ambient temperature for 14 h. The reaction mixture was quenched by the dropwise addition of saturated aqueous sodium hydrogen carbonate until effervescence ceased and then diluted with ethyl acetate (10 cm^3). Ether extraction and chromatography [light petroleum–ethyl acetate (2:1)] afforded the *title compound* **71** (6 mg, 43%) as a colourless oil; ν_{max}/cm^{-1} 3404, 1713, 1423, 1283, 1066, 1022 and 922; δ_H(300 MHz; C_6D_6) 1.5 (1 H, br s, OH), 1.27 (1 H, qd, *J* 13.2, 3.6, 3-H_{ax}), 1.51 (1 H, dd, *J* 13.2, 12, 5-H_{ax}), 1.78–1.99 (1 H, m, 3-H_{eq}), 2.0–2.26 (4 H, m), 2.39 (1 H, m), 2.45 (1 H, d, *J* 14.4, 11-H_{ax}), 2.68 (1 H, dd, *J* 14.4, 0.55, 11-H_{eq}), 2.68 (1 H, td, *J* 13.2, 2.5), 2.98 (1 H, ddd, *J* 15.6, 12, 3.6) and 3.71 (1 H, m, 4-H).

p-Nitrobenzoyl chloride (27 mg, 0.147 mmol) was added to a solution of the dithiospiroacetal **71** (16 mg, *ca.* 0.073 mmol), triethylamine (41 cm^3, 0.294 mmol) and 4-dimethylaminopyridine (1 mg, 0.008 mmol) in dichloromethane (1 cm^3) at 0 °C. The mixture was stirred at 0 °C for 3 h and at ambient temperature for 1.5 h, after which triethylamine (41 cm^3, 0.294 mmol), 4-dimethylaminopyridine (1 mg, 0.008 mmol) and *p*-nitrobenzoyl chloride (27 mg, 0.147 mmol) were added to it. After being stirred for a further 1.5 h at ambient temperature

Table 1 Fractional coordinates (esd) compound **18**

Atom	*x*	*y*	*z*
S(7)	0.026 88(5)	0.008 03(2)	0.309 60(7)
O(1)	−0.037 0(1)	0.073 12(6)	0.340 8(1)
O(4A)	0.127 3(2)	0.086 29(8)	0.525 0(2)
O(10A)	−0.082 2(1)	0.074 67(6)	0.135 8(2)
O(10B)	0.003 0(1)	0.069 71(8)	0.027 3(2)
C(2)	−0.047 9(2)	0.066 6(1)	0.444 3(2)
C(3)	0.006 6(2)	0.084 1(1)	0.506 7(3)
C(4)	0.073 0(2)	0.068 7(1)	0.474 9(2)
C(5)	0.082 0(2)	0.074 3(1)	0.364 7(2)
C(6)	0.024 1(1)	0.059 35(8)	0.304 2(2)
C(8)	−0.040 5(2)	−0.000 5(1)	0.224 0(3)
C(9)	−0.025 5(2)	0.015 3(1)	0.122 2(3)
C(10)	−0.019 5(2)	0.057 4(1)	0.122 3(2)
C(11)	0.029 8(2)	0.072 5(1)	0.197 2(2)
C(12)	−0.110 3(2)	0.081 7(1)	0.041 6(3)
C(13)	−0.053 7(2)	0.079 2(1)	−0.029 6(3)

the reaction mixture was quenched with saturated aqueous ammonium chloride (2 cm^3) and diluted with ethyl acetate (5 cm^3). Extraction into ethyl acetate and chromatography [light petroleum–ether (1:1)] afforded the p-*nitrobenzoate* **72** (21 mg, 78%) as a crystalline solid, m.p. 165–167 °C (Found: M^+, 367.0564. $C_{16}H_{17}NO_5S_2$ requires *M*, 367.0548); ν_{max}/cm^{-1} 1720, 1607, 1527, 1350, 1275, 1104 and 721; δ_H(500 MHz; C_6D_6) 1.43 (1 H, qd, *J* 12, 3, 3-H_{ax}), 1.67 (1 H, t, *J* 12.5, 5-H_{ax}), 1.93–2.0 (1 H, m, 3-H_{eq}), 2.01 (1 H, dt, *J* 14, 4, 2-H_{eq}), 2.06 (1 H, ddd, *J* 14, 11, 5, 9-H_{ax}), 2.24 (1 H, dt, *J* 13, 5, 8-H_{eq}), 2.28 (1 H, d, *J* 13.1, 4.0, 5-H_{eq}), 2.37 (1 H, dt, *J* 14.4, 4, 9-H_{eq}), 2.47 (1 H, d, *J* 13.5, 11-H_{ax}), 2.67 (1 H, d, *J* 13.5, 11-H_{eq}), 2.75 (1 H, ddd, *J* 14.6, 12.1, 2.4, 2-H_{ax}), 2.86 (1 H, ddd, *J* 13.7, 11.4, 3.8, 8-H_{ax}), 5.45 (1 H, tt, *J* 12, 4.5, 4-H_{ax}) and 7.75–7.88 (4 H, m, ArH); *m/z* (EI) 367 (M^+, 0.8%).

X-Ray Crystallographic Structure Determinations.—Crystal data for compound **18**. $C_{11}H_{18}O_4S$, *M* = 246.32, colourless, block, m.p. 128.5–129.5 °C, crystal dimensions 0.4 × 0.4 × 0.5 mm^3, orthorhombic, *a* = 20.158(4), *b* = 35.775(6), *c* = 13.523(5) Å; *U* = 9752(4) $Å^3$, space group *Fddd* (70), *Z* = 32, D_c = 1.342 g cm^{-1}, graphite monochromated Mo-Kα radiation (λ = 0.710 69 Å), μ(Mo-Kα) = 2.50 cm^{-1}, *F*(000) = 4224.

Measurements were made on a Rigaku AFC6S diffractometer at 296 K; lattice parameters from the setting angles of 25 reflections in the range $28.07 < 2\theta < 36.77°$; ω-2θ scans, maximum $2\theta = 50.0°$ ($0 < h < 24$, $0 < k < 43$, $0 < l < 16$); scan width $(1.15 + 0.30 \tan \theta)°$ and scan speed 8.0° min^{-1} (in omega); weak reflections [$I < 10.0\ \sigma(I)$] rescanned (maximum of 2 rescans); 2238 unique reflections collected, with 1351 considered observed [$I > 3.00\ \sigma(I)$]; intensities of three standard reflections measured after 150 reflections did not change significantly; empirical absorption correction based on azimuthal scans of three reflections was applied, resulting in transmission factors ranging from 0.84 to 1.00; Lorentz and polarization corrections applied. The structure was solved using the direct methods program MITHRIL and DIRDIF.[27] The non-hydrogen atoms were refined anisotropically. Hydrogen atoms were found in successive difference Fourier maps, and refined isotropically. Full-matrix least-squares of 217 parameters minimized the function $\Sigma\omega(|F_o| - |F_c|)^2$. The weighting scheme was based on counting statistics. Final $R = 0.042$, $R_\omega = 0.47$, maximum shift/error = 1.7 and the standard deviation of an observation of unit weight, $S = 1.75$. The maximum and minimum peaks on the final difference Fourier map corresponded to 0.25 and −0.24 $eÅ^{-3}$, respectively. Neutral atom scattering factors were used, anomalous dispersion effects were included in F_{calc};[28] the values for $\Delta f'$ and $\Delta f''$ were those of Cromer.[29] All calculations were performed using the TEXSAN[20] crystallographic software package of the Molecular Structure Corporation. Atomic coordinates are given in Table 1.*

Table 2 Fractional coordinates (esd) compound **49**

Atom	*x*	*y*	*z*
S(1)	0.073 57(7)	−0.084 2(2)	0.143 59(8)
S(7)	0.163 19(7)	0.271 6(1)	0.228 39(8)
O(12)	0.274 6(2)	−0.217 9(4)	0.423 5(2)
O(14)	0.350 9(2)	0.040 2(4)	0.479 5(2)
O(22)	0.579 1(2)	−0.789 1(5)	0.704 6(2)
O(23)	0.646 7(2)	−0.549 8(5)	0.780 8(2)
N(21)	0.588 5(2)	−0.620 3(6)	0.717 9(3)
C(2)	0.060 0(3)	−0.116 4(7)	0.259 9(4)
C(3)	0.131 5(3)	−0.217 7(7)	0.333 6(4)
C(4)	0.210 0(2)	−0.107 3(6)	0.354 6(3)
C(5)	0.234 6(3)	−0.072 5(7)	0.265 8(3)
C(6)	0.172 9(2)	0.037 1(6)	0.183 6(3)
C(8)	0.100 2(4)	0.376 1(8)	0.114 9(4)
C(9)	0.139 3(4)	0.364 1(9)	0.037 2(4)
C(10)	0.151 3(4)	0.164 1(9)	0.011 4(3)
C(11)	0.203 8(3)	0.050 7(9)	0.097 3(4)
C(13)	0.342 5(3)	−0.127 9(6)	0.478 3(3)
C(15)	0.406 1(2)	−0.260 7(6)	0.538 7(3)
C(16)	0.392 5(2)	−0.452 2(6)	0.537 0(3)
C(17)	0.451 8(2)	−0.570 5(6)	0.594 6(3)
C(18)	0.525 3(2)	−0.494 0(6)	0.654 3(3)
C(19)	0.541 1(3)	−0.304 5(7)	0.655 9(3)
C(20)	0.481 4(3)	−0.188 2(6)	0.597 3(3)

Crystal data for compound **49**. $C_{16}H_{19}NO_4S_2$, *M* = 353.45, colourless, plate, m.p. 145–147 °C, crystal dimensions 0.03 × 0.12 × 0.5 mm^3, monoclinic, *a* = 17.199(2), *b* = 7.126(2), *c* = 14.603(2) Å; *b* = 109.651(7)°; *U* = 1685.6(9) $Å^3$, space group $P2_1/c$ (14), *Z* = 4, D_c = 1.393 g cm^{-1}, graphite monochromated Cu-Kα radiation from a 12 kW rotating anode source; (λ = 1.541 78 Å), μ(Cu-Kα) = 29.78 cm^{-1}, *F*(000) 744. Measurements were made on a Rigaku AFC5R diffractometer at 295 K; lattice parameters from the setting angles of 21 reflections in the range $63.19 < 2\theta < 78.79°$; ω-2θ scans, maximum $2\theta = 120.0°$ ($-19 < h < 19$, $0 < k < 8$, $0 < l < 16$); scan width $(1.15 + 0.30 \tan \theta)°$ and scan speed 32.0° min^{-1} (in omega); weak reflections [$I < 10.0\ \sigma(I)$] rescanned (maximum of 2 rescans); 2846 reflections were collected, 2728 were unique (R_{int} = 0.036), with 1921 considered observed [$I > 3.00\ \sigma(I)$]; intensities of three standard reflections measured after every 150 reflections did not change significantly; empirical absorption correction based on azimuthal scans of three reflections was applied, resulting in transmission factors ranging from 0.72 to 1.00; Lorentz and polarization corrections applied. The structure was solved by direct methods using the program SHELXS.[31] The non-hydrogen atoms were refined anisotropically. Hydrogen atoms were found in successive difference Fourier maps, and refined isotropically. Full-matrix least squares of 284 parameters minimized the function $\Sigma\omega(|F_o| - |F_c|)^2$. The weighting scheme was based on counting statistics. The final $R = 0.052$, $R_\omega = 0.064$, maximum shift/error = 0.01 and the standard deviation of an observation of unit weight, $S = 1.96$. The maximum and minimum peaks on the final difference Fourier map corresponded to 0.34 and −0.22 $eÅ^{-3}$, respectively. Calculations were carried out using sources for scattering factors and software described for compound **18**. Atomic coordinates are given in Table 2.*

* Supplementary material (see Instructions for Authors, 1992, section 5.6.3, January issue); tables of thermal parameters, bond lengths and bond angles are available on request from the Cambridge Crystallographic Data Centre.

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