Control over absolute (*R,S*), relative (*syn,anti*) and geometrical (*E,Z*) stereochemistry in the synthesis of allylically substituted alkenes from diphenylphosphinoyl epoxy alcohols

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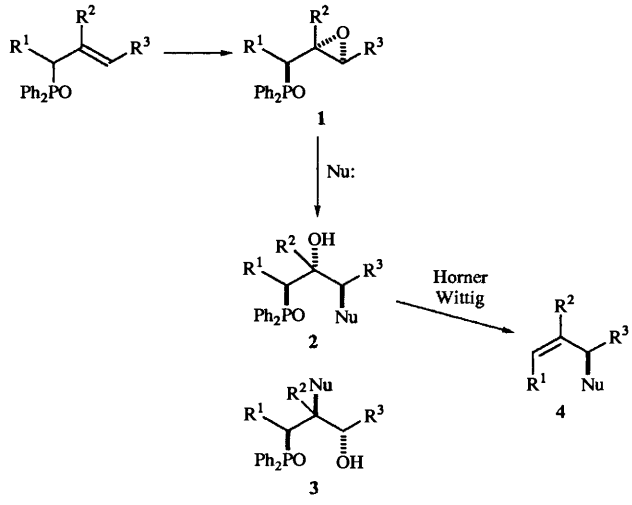
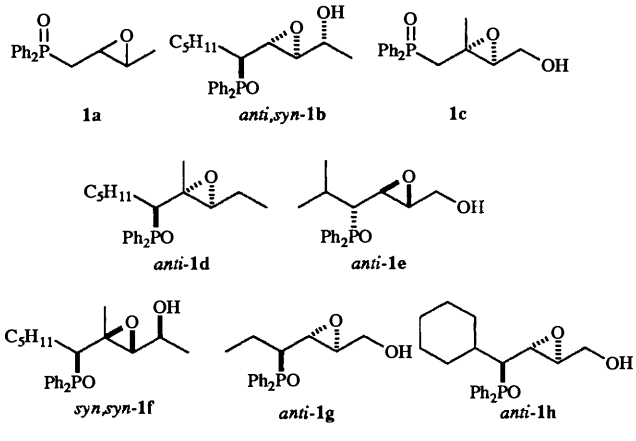
Regioselective ring-openings of epoxy alcohols bearing a diphenylphosphinoyl (Ph_2PO) group give diols which can undergo stereospecific Horner–Wittig elimination. This method was used to make allylic alcohols, unsaturated β-hydroxy sulfides, homoallylic alcohols and unsaturated amino acids, with control over their absolute (*R,S*), relative (*syn,anti*) and geometrical (*E,Z*) stereochemistry.

The diphenylphosphinoyl group came to the attention of synthetic chemists because of its ability to participate in a stereospecific elimination, the Horner–Wittig reaction.[1] Conjugated double bonds can be formed directly from allylic phosphine oxides and aldehydes using lithium bases.[2] However, if conditions are controlled more carefully, or if the phosphine oxide component is not allylic or benzylic,[3] the reaction stops after addition of the aldehyde, and elimination does not take place. The resulting β-hydroxy phosphine oxides are stable, often crystalline, and easily purified. Subsequent stereospecific elimination using a sodium or potassium base from a single diastereoisomer of the β-phosphine oxide adduct can lead to alkenes with high geometrical purity.[1]

The value of the diphenylphosphinoyl group as a precursor to stereochemically pure double bonds is dependent upon its ability to control the three-dimensional relative stereochemistry of the β-hydroxy phosphine oxide intermediate. We have demonstrated that this can be achieved by a variety of methods,[4] some of which[5] also allow control of more remote chiral centres. Most recently, we have described the power of the diphenylphosphinoyl group to direct some enantio-[6] and diastereo-selective[7] epoxidations. In this paper[8] we describe the stereospecific transformation of the products **1** of these epoxidations into single diastereoisomers of β-hydroxy phosphine oxides **2** containing three or four controlled chiral centres (Scheme 1). We also describe the Horner–Wittig elimination of these compounds, which sacrifices two of these chiral centres to give a double bond of controlled geometry, leaving behind the remaining chiral centres with controlled relative and absolute stereochemistry. This strategy has allowed us to synthesise single stereoisomers of a variety of allylically substituted alkenes **4**, some with potential biological applications as leukotriene analogues or unsaturated amino acids. The method is stereochemically general: it is often possible to synthesise any one diastereoisomer or enantiomer of the product at will by minor variations in the synthetic route.



Scheme 1



The regioselectivity of nucleophilic attack on diphenylphosphinoyl epoxides

To reveal the hydroxyl group required in the Horner–Wittig elimination, the epoxides **1** must be opened with nucleophiles. Of the two possible regioisomeric products **2** and **3** from this reaction, only **2**, with the hydroxyl group β to phosphorus, is of use. We will start with a description and an analysis of the regioselectivity of this reaction. We will then go on to outline ways in which this regioselectivity may be modified to a point where synthetically useful reactions emerge. Finally, we will describe the use of the Payne rearrangement to direct nucleophilic attack to further electrophilic centres in **1**.

Our preliminary investigations into the opening of the epoxides **1** are detailed in Table 1. The regioselectivity depended heavily on the substitution pattern of the epoxide, with steric factors playing an important role. In the absence of substituents R^1 and R^2, the 'natural' regioselectivity of the system appears marginally to favour attack at the unwanted, β to phosphorus, end of the epoxide (entry 1). This 'natural' regioselectivity is enhanced in the case of the epoxy alcohols **1b** (entries 2 and 3).

Table 1 Regioselectivity of nucleophilic attack on Ph_2PO epoxides

Entry	Starting material **1**	R^1	R^2	R^3	Nucleophile	β-Opened product, yield (%)	γ-Opened product, yield (%)
1	**1a**	H	H	Me	PhSLi	**5**, 46	**6**, 21
2	*anti,syn*-**1b**	C_5H_{11}	H	CHOHMe	$Ph(CH_2)_3SLi$	**7**, 60	0
3	*anti,syn*-**1b**	C_5H_{11}	H	CHOHMe	$Ph(CH_2)_3SNa$	**7**, 66	0
4	**1c**	H	Me	CH_2OH	PhSNa	0	**8**, 100
5	*anti*-**1d**	C_5H_{11}	Me	Et	PhSLi	**9**, 25	**10**, 37
6	*anti*-**1e**	Pr^i	H	CH_2OH	PhSNa	0	**11**, 18
7	*anti*-**1e**	Pr^i	H	CH_2OH	NH_4N_3	**120**, 9	**13**, 13
8	*anti*-**1e**	Pr^i	H	CH_2OH	thymineNa	0	0[a]

[a] 66% Yield of the *E*-vinyl phosphine oxide **14**.

Table 2 Lewis acid-catalysed nucleophilic opening of Ph_2PO epoxides

Entry	Starting material	R^1	R^2	R^3	Nucleophile	Lewis acid	β-Opened product, yield (%)	γ-Opened product, yield (%)
1	*anti*-**1d**	C_5H_{11}	Me	Et	PhSH	Me_3Al	**9**, < 10[a]	**10**, 59
2	*syn,syn*-**1f**	C_5H_{11}	Me	CHOHMe	$Ph(CH_2)_3SH$	Me_3Al	**15**, 11	**16**, 16
3	*anti,syn*-**1b**	C_5H_{11}	H	CHOHMe	$Ph(CH_2)_3SH$	Me_3Al	**7**, 9	**17**, 31[b]
4	*anti*-**1e**	Pr^i	H	CH_2OH	$Ph(CH_2)_3SH$	Me_3Al	0	**18**, 69
5	*syn*-**1e**	Pr^i	H	CH_2OH	$Ph(CH_2)_3SH$	Me_3Al	0	**19**, 46
6	*syn*-**1e**	Pr^i	H	CH_2OH	Bu^tSH	Me_3Al	0	**20**, 6; **21**, 51
7	*anti*-**1e**	Pr^i	H	CH_2OH	Me_3Al	Me_3Al	0	0[c]
8	*syn*-**1e**	Pr^i	H	CH_2OH	Me_3Al	Me_3Al	0	**21**, 62
9	*anti*-**1e**	Pr^i	H	CH_2OH	Me_3SiN_3	$Ti(O^iPr)_4$	0	0[d]
10	*syn*-**1e**	Pr^i	H	CH_2OH	Me_3SiN_3	$Ti(O^iPr)_4$	0	**22**, 61
11	*anti*-**1g**	Et	H	CH_2OH	Me_3SiN_3	$Ti(O^iPr)_4$	**23**, 27	**24**, 19
12	*syn*-**1g**	Et	H	CH_2OH	Me_3SiN_3	$Ti(O^iPr)_4$	**25**, 21	**26**, 39
13	*anti*-**1e**	Pr^i	H	CH_2OH	$Me_2AlNHBn$	Me_3Al	0	**27**[e]
14	*syn*-**1e**	Pr^i	H	CH_2OH	$Me_2AlNHBn$	Me_3Al	0	**28**, 19[f]

[a] By NMR. [b] The δ-opening product **29** was also isolated in 10% yield. This probably results from a Lewis acid-catalysed Payne rearrangement (P. C. Bulman Page, C. M. Rayner and I. O. Sutherland, *J. Chem. Soc., Perkin Trans. 1*, 1990, 1375). [c] Starting material recovered in 45% yield. [d] Starting material recovered. [e] At room temperature, a low yield of a mixture of starting material and the desired product was obtained. At reflux in dichloromethane, a 55% yield of the *Z*-vinyl phosphine oxide **30** was obtained. [f] Starting material recovered in 25% yield.

No addition was observed γ to phosphorus in these compounds, probably because of the inductive effect of the neighbouring hydroxyl group.[9] The γ : β regioselectivity is greatly increased if the β position bears a substituent. The epoxy alcohol **1c** reacted with complete regioselectivity for the desired γ position (entry 4). Surprisingly, the reaction of **1d** was less regioselective, despite the absence of a δ hydroxyl group in this compound (entry 5). With $R^1 = Pr^i$, β opening is disfavoured, and the reactions proceed more slowly and are low yielding (entries 6 and 7). The X-ray crystal structure of *anti*-**1e**[6] † suggests that the diphenylphosphinoyl group may shield the rear side of the epoxide in this compound in a conformation stabilised by the bulky group attached to the carbon α to phosphorus. The sodium salt of thymine acted as a base rather than as a nucleophile, catalysing rearrangement of the epoxide *anti*-**1e** to the *E*-vinyl phosphine oxide **14**. The sensitivity of the regioselectivity observed in epoxide openings to both steric and electronic effects has been demonstrated by Sharpless.[9]

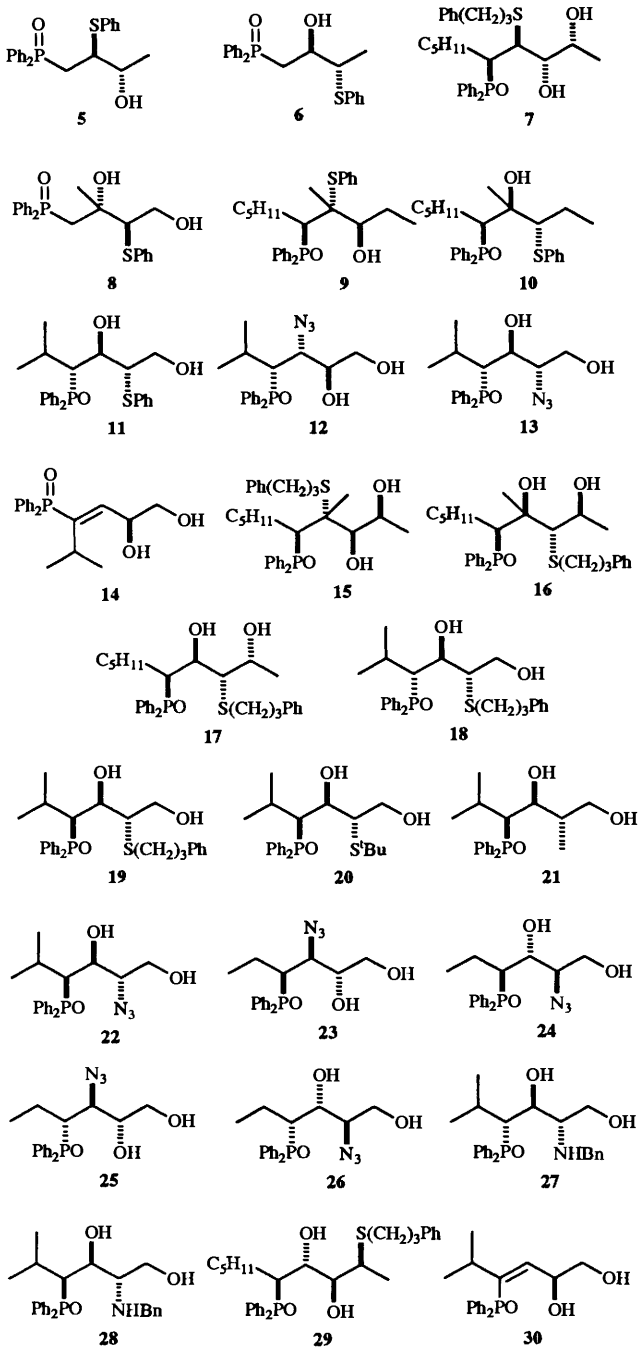
Attack of sulfur and nitrogen nucleophiles on our epoxides was more successful under Lewis acid catalysis (Table 2). The reaction of *anti*-**1d** with benzenethiol in the presence of trimethylaluminium (entry 1) proceeded in similar yield to, but with greater desired γ selectivity than, its uncatalysed reaction with PhSLi (Table 1, entry 5). Thiol attack on the epoxides *syn,syn*-**1f** and *anti,syn*-**1b** was also slightly γ selective in the presence of trimethylaluminium, and we were able to isolate the desired β-hydroxy phosphine oxides **16** and **17** from these reactions in low yield (entries 2 and 3). As with the reactions in Table 1, this γ selectivity was increased when the group α to phosphorus was more bulky: for the epoxides *anti*- and *syn*-**1e** (which have $R^1 = Pr^i$), none of the β-opened product was observed, and the β-hydroxy phosphine oxides **18** and **19** were isolated in good yield (entries 4 and 5).

Interestingly, addition of the more bulky 1,1-dimethylethanethiol to *syn*-**1e** proceeded only in low yield (6%; entry 6): the major product from this reaction was transfer of a methyl group from the trimethylaluminium to give the diol **21**. This diol could also be made in good yield simply by refluxing the epoxide *syn*-**1e** with trimethylaluminium in dichloromethane (entry 7). The *anti* diastereoisomer of this epoxide, *anti*-**1e**, failed to react with trimethylaluminium (entry 8).

Nitrogen nucleophiles, under Lewis acid catalysis, behaved similarly. Trimethylsilyl azide–titanium tetraisopropoxide[10] reacted with *syn*-**1e** to give solely the γ opened epoxide **22** (entry 9), though, like trimethylaluminium, it would not react with *anti*-**1e**. Moving to the less crowded epoxides **1g** (with $R^1 = Et$) exchanged lack of reactivity in the *anti* diastereoisomer for lack of regioselectivity: both *syn*- and *anti*-**1g** gave mixtures of β and γ products **23** + **24** and **25** + **26** (entries 10 and 11).

The aluminium amine complex $Me_2AlNHBn$,[11] which has much greater nucleophilicity towards epoxides than benzylamine itself, was remarkably unreactive towards both *syn*- and *anti*-**1e** (entries 12 and 13). In both cases, some amino diol product **27** or **28** was formed, but the reaction did not reach completion. An attempt to force the reaction by refluxing *anti*-**1e** with $Me_2AlNHBn$ in dichloromethane overnight resulted in

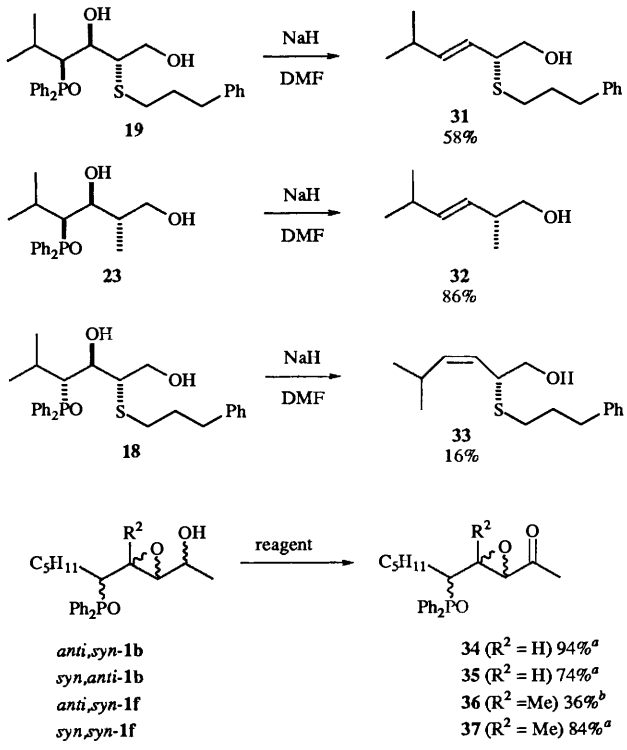
† We use the terms *anti* and *syn* as defined by Masamune (S. Masamune, S. A. Ali, D. L. Snitman and D. S. Garvey, *Angew. Chem., Int. Ed. Engl.*, 1980, 557) starting from the left of the molecule as drawn and ignoring the fixed (*trans*) relationship across the epoxide.



rearrangement to the *Z*-vinyl phosphine oxide **30** in 55% yield.

The effect of the Lewis acids (trimethylaluminium or titanium tetraisopropoxide) on the regioselectivity of these epoxide openings is surprising. Both these reagents have been used widely in the past precisely because they promote regioselective nucleophilic attack at C-3‡ (the β carbon of our epoxy alcohols).[10,12] The usual explanation[10c] for this mode of action is the chelating effect of the epoxy and hydroxy oxygen atoms. The complete C-2 (γ) selectivity achieved in the reactions of *syn*-**1e** in the presence of these reagents (Table 2, entries 4, 5, 6, 8 and 10) is probably partly due to competing alternative chelation by the epoxy and the phosphoryl oxygen atoms. The relative unreactivity of *anti*-**1e**, which gives no addition product with trimethylaluminium or trimethylsilyl azide–titanium tetraisopropoxide, could be due to a steric interaction which blocks formation or reaction of this complex for the *anti* diastereoisomer.

‡ In Sharpless's numbering system for epoxy alcohols,[9] C-1 refers to the carbon atom bearing the hydroxyl group (the carbon δ to phosphorus in our diphenylphosphinoyl epoxy alcohols), and C-2 and C-3 to the carbon atoms carrying the epoxide (respectively γ and β to phosphorus in our compounds).



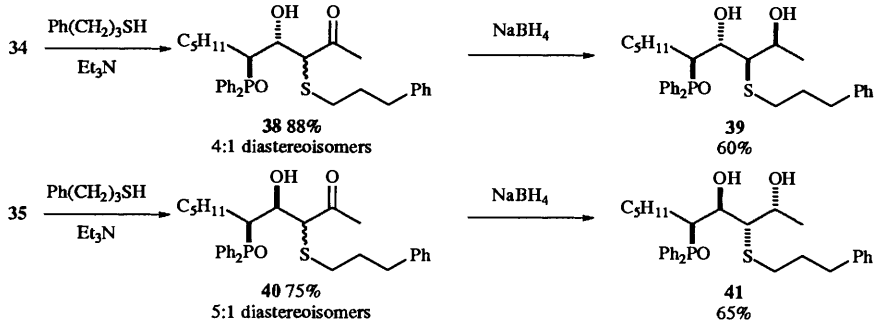
Scheme 2

The additional importance of a steric contribution to the γ regioselectivity observed in the reactions of **1** is demonstrated by the contrastingly unselective reactions of the less crowded epoxides **1b** (R^1 = pentyl) and **1g** (R^1 = Et) (Table 2, entries 3, 11 and 12). Both diastereoisomers reacted to give mixtures of regioisomers.

The reaction sequence was completed by treating the three enantiomerically enriched diols **19, 21** and **18** with sodium hydride in DMF (Scheme 2).[1] They each underwent stereospecific Horner–Wittig elimination, to give the *E* homoallylic alcohols **31** and **32** in good yield from the *syn* β-hydroxy phosphine oxides **19** and **21**, and the *Z* homoallylic alcohol **33** in poor yield from the *anti* β-hydroxy phosphine oxide **18**. The geometries of the double bonds were determined by ^{1}H NMR coupling constants of the two olefinic protons (15.5 Hz for the two *E* alkenes **31** and **32**; 10.4 Hz for the *Z* alkene **33**), and since the Horner–Wittig elimination is stereospecific, this allowed us to confirm the sense of the diastereoselectivity in our epoxidation reactions.[6,7] The values of $^3J_{PCHCHOH}$ for all the β-hydroxy phosphine oxides formed by γ-opening of the epoxides **1** were also characteristic of their stereochemistry.[13] The sign of the optical rotation of the homoallylic alcohol **32** was in agreement with that of the literature value[14] for this enantiomer.

γ-Regioselectivity controlled by oxidation

A hydroxyl substituent lowers the rate of nucleophilic substitution at an adjacent electrophilic centre. In the absence of other steric or electronic effects, nucleophilic attack on epoxy alcohols is therefore C-3 selective.[9] A carbonyl substituent, on the other hand, increases the rate of nucleophilic substitution at



Scheme 3

an adjacent electrophilic centre.[15] Oxidation of epoxy alcohols to epoxy carbonyl compounds can therefore provide a means of reversing the regioselectivity of their opening reactions.[9]

We applied this strategy to our epoxides, and in this way were able to open them with complete γ regioselectivity. The epoxy alcohols **1b** and **1f** were oxidised (most efficiently with Jones' reagent) to the four epoxy ketones **34**–**37**. Attack of $Ph(CH_2)_3SH$ on these ketones gave only the γ-opening product: **34** and **35** gave the sulfides **38** and **40** in high yield (Scheme 3). The stereospecifity of these reactions was, however, incomplete, and in each case, about 20% epimerisation was observed.

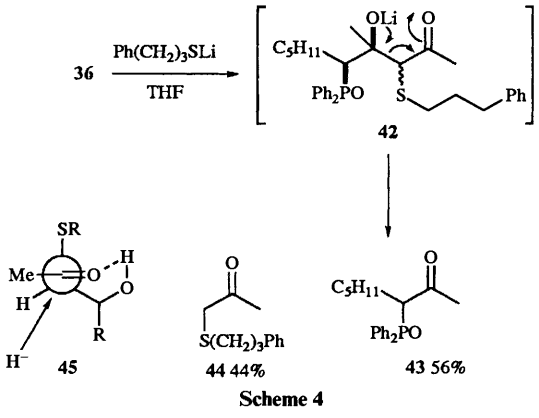
Reaction of the ketone **36** with $Ph(CH_2)_3SH$ occurred more slowly, and the ring-opened product was unstable under the number of conditions tried. Fragmentation of the first-formed alkoxide **42** gave two ketones **43** and **44** which were isolated in 56 and 44% yield, respectively (Scheme 4).

The two epimeric mixtures of ketones **38** and **40** were stereoselectively reduced with sodium borohydride back to the diols **39** and **41**, both of which were isolated as single diastereoisomers in high yield. The stereochemistry of the reduction was established by comparing the ^1H NMR spectra of these compounds with those of the diols produced by direct epoxide opening of *anti,syn*-**1b** with the thiolate. Attack of the reducing agent appears to be directed solely by the sulfide substituent α to the ketone, which will prefer to occupy the perpendicular position in the Felkin–Anh[16] conformation **45**. This conformation is additionally stabilised by hydrogen bonding between the hydroxyl group and the ketone, and made more reactive by interaction between the C=O π* and the C–S σ*.[17] The importance of the hydrogen bond is demonstrated by comparison of the stereoselectivity of this reduction with the lower stereoselectivity in the reduction of β-keto sulfides lacking the hydroxyl group.[18]

Treatment of the racemic diols **17**, **39**, **41** and **16** with sodium hydride in DMF gave the unsaturated β-hydroxy sulfides **46**, **47**, **49** and **50** respectively (Scheme 5), with control over the geometry of the double bond and the relative stereochemistry of the two remaining chiral centres. These compounds are precursors of leukotriene analogues.[19] The elimination leading to the disubstituted *E* alkene **49** was higher yielding than the eliminations leading to trisubstituted or to *Z* alkenes, which were also accompanied by side-reactions. For example, the allylic sulfide **48**, probably formed by decomposition of the desired product **47**, was isolated in substantial yield from the elimination of **39**. The major product from the elimination of **15** was hexyldiphenylphosphine oxide **51**.

Unsaturated amino acids (Scheme 6)

The principle of carbonyl-directed epoxide opening was also applied to the enantiomerically enriched epoxy alcohols *syn*- and *anti*-**1e** and *syn*- and *anti*-**1h**. These were oxidised ($RuCl_3$, $NaIO_4$, MeCN)[20] to the epoxy acids **52**, **55**, **58** and **61** in excellent yield. Treatment of these acids with refluxing aqueous



Scheme 4

benzylamine[21] gave the insoluble amino acids **53**, **56**, **59** and **62**, which could be esterified with diazomethane to give the more easily handled amino esters **64**–**67** in quantitative yield. No regioisomers or epimers were observed after esterification.

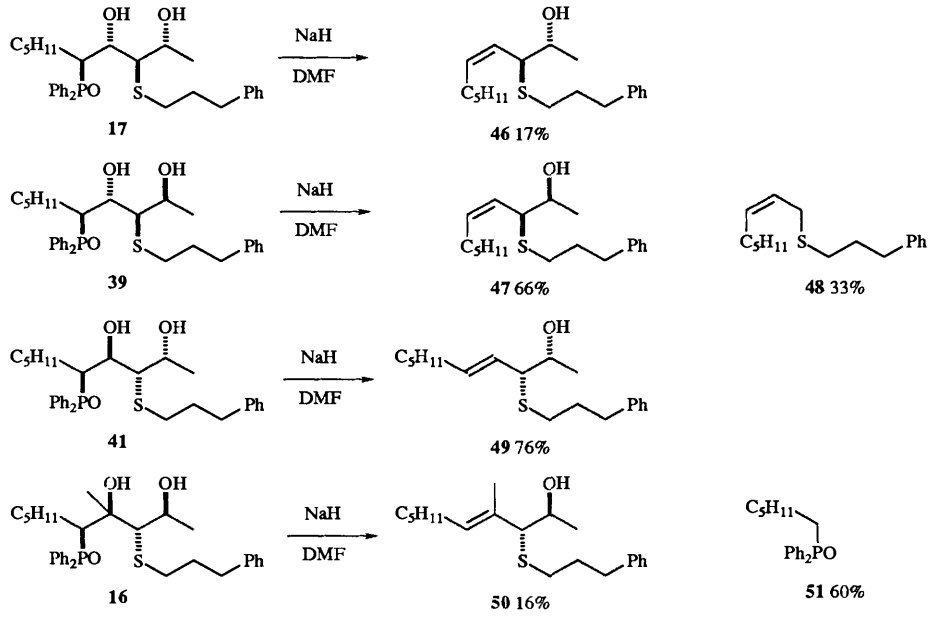
Horner–Wittig elimination of these amino acids was best accomplished from the sodium dianions (sodium hydride in DMF) of **53** and **59** and from the potassium dianions (potassium hydroxide in DMSO) of the *anti* compounds **56** and **62** (Scheme 7). The unsaturated amino acid products were isolated by diazomethane esterification of the complete reaction mixture, giving single geometrical isomers of the enantiomerically enriched *N*-benzylated unsaturated α-amino acid methyl esters **54**, **57**, **60** and **63** in moderate yield. Unsaturated amino acids have antimicrobial activity,[22] and are useful for tools for the investigation of biochemical mechanisms.[23]

This elimination is rather remarkable since it forms a β,γ-unsaturated acid without isomerisation under very basic conditions. Moreover, chiral shift studies of **54** and **55** with 1-(9-anthryl)-2,2,2-trifluoroethanol[24] showed that the enantiomeric excess of the final unsaturated amino ester products remained more or less intact (63 and 67% ee from the epoxides *syn*- and *anti*-**1e** of 65 and 85% ee, respectively): little racemisation had taken place.§ Racemisation, double bond migration, and lack of geometrical selectivity are problems in many of the published asymmetric syntheses of β,γ-unsaturated amino acids.[25]

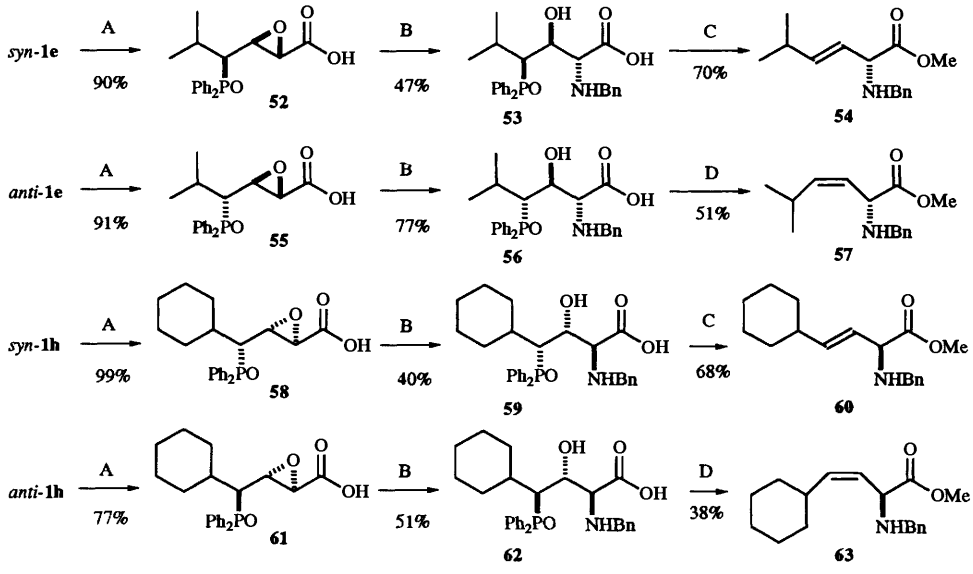
An attempt to eliminate sodium diphenylphosphinate from the ester **64** with sodium hydride in DMF gave a result reminiscent of the fragmentation which resulted from attack of nucleophiles on **37**. Only the aldehyde **68** was isolated from the reaction, in 22% yield. The use of dianions discourages this fragmentation.

Reduction of the esterified phosphine oxides **64** and **65** back

§ The purification of the amino acids by crystallisation could also have altered the enantiomeric excesses.



Scheme 5



Scheme 6 *Reagents:* A, $NaIO_4$, $RuCl_3$ (cat.), MeCN, H_2O, CCl_4; B, $BnNH_2$, H_2O, reflux; C, (1) NaH, DMF; (2) CH_2N_2; D, (1) KOH, DMSO; (2) CH_2N_2

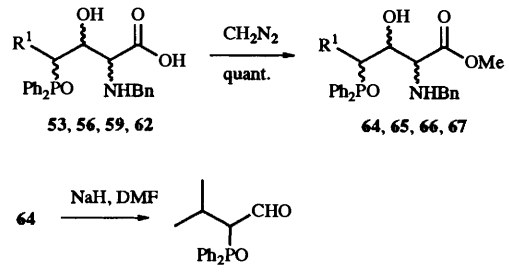
to primary alcohols **28** and **27**, representing overall γ selective addition of benzylamine to the epoxy alcohols **1e** was achieved using lithium borohydride–methanol in THF.[26] This reduction was accompanied by a small amount of epimerisation, but the major diastereoisomers were, in each case, identical with the products formed in low yield by addition of $Me_2AlNHBn$ to the appropriate epoxy alcohol (Table 2, entries 13 and 14).

δ-Regioselective openings by controlled Payne rearrangement

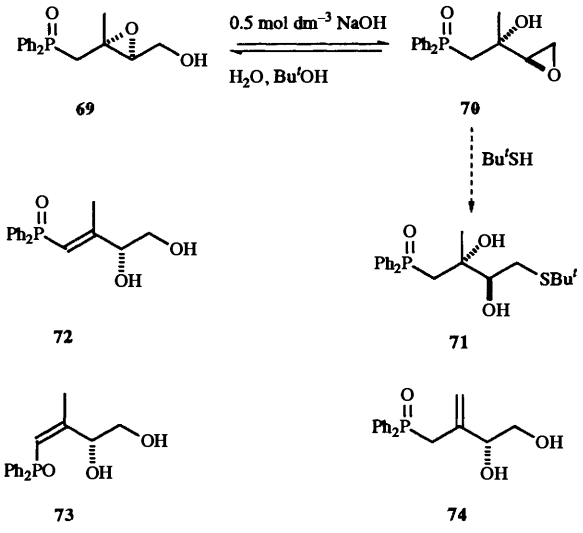
In some ingenious work on the regioselective ring openings of the epoxy alcohols, Sharpless[27] has demonstrated that it is possible to direct nucleophilic attack to C-1 (the carbon atom bearing the hydroxyl group) by using a controlled Payne rearrangement.[28] He developed two complementary methods, the 'diol sulfide' and 'diol sulfonate' routes. We applied both of these routes to our diphenylphosphinoyl epoxy alcohols, and found the 'diol sulfonate' route, which avoids basic conditions, more suited to our base-sensitive compounds. Using this route, we were able to demonstrate the synthesis of some enantiomerically enriched allylic alcohols, though not with the same success as for the C-2-directed openings just described.

In the manner of the 'diol sulfide' route, the epoxy alcohol **69** was dissolved in 0.5 mol dm^{-3} aqueous sodium hydroxide in an attempt to form a Payne equilibrating mixture of epoxide regioisomers **69** and **70** (Scheme 8). A solution of 1,1-dimethylethanethiol was added slowly to this mixture, to trap the more reactive terminal epoxide. However, when the product mixture from this reaction was examined by NMR, it was found to contain none of the hoped-for terminal sulfide **71**. Instead, a mixture of three elimination products **72**, **73** and **74** was formed.

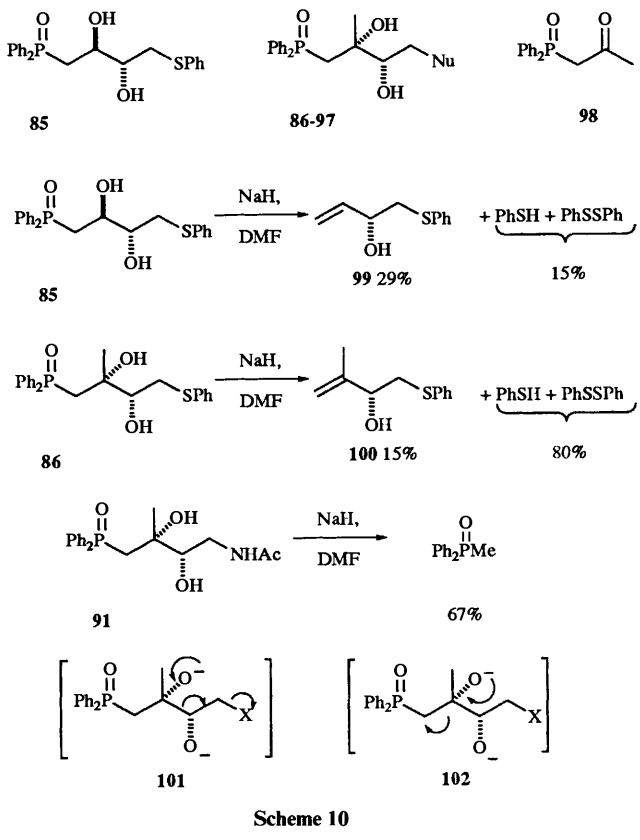
Turning to the 'diol sulfonate' route, we treated the three epoxides **69**, **77** and **81** with methanesulfonyl chloride and triethylamine to give the mesylates **75**, **78** and **82** in excellent yield. These epoxy mesylates were surprisingly resistant to acid-catalysed ring opening in aqueous DMSO. Reaction of the *cis* epoxide **78** needed 2 equivalents of acid, and took 45 h to



Scheme 7



Scheme 8

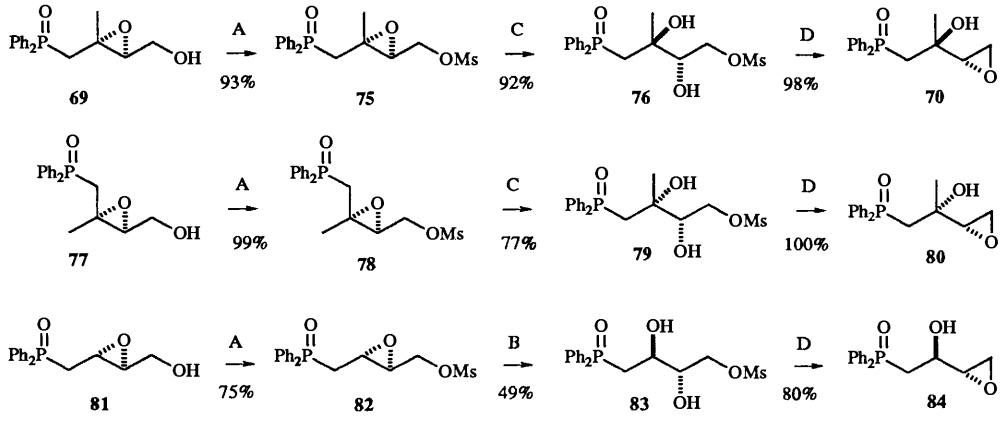


Scheme 10

reach completion, while the *trans* epoxide **75** needed 7 days under these conditions. Nonetheless, high yields of the diols **76** and **79** were obtained. Reaction in refluxing THF was faster (complete in 2–4 h), but gave low yields. The unsubstituted epoxy mesylate **82** was even more inert. Its reaction with water was only complete after refluxing in aqueous THF with 2 equiv. of perchloric acid for 42 h. Attempted ring opening in DMSO returned only starting material.

Ring closure to the terminal epoxide was easily achieved by stirring the diols with potassium carbonate in methanol for a few minutes. High yields of the three epoxides **70**, **80** and **84** were obtained (Scheme 9). The enantiomeric excesses of the three terminal epoxides were determined by ^{1}H NMR spectroscopy in the presence of 1-(9-anthryl)-2,2,2-trifluoroethanol.[24] The methyl-substituted compounds showed no loss of enantiomeric purity during the reaction sequence: starting materials **69** and **77** with enantiomeric excesses of 97 and 77%, respectively, gave the products **70** and **80** with enantiomeric excesses of >95 and 73%. The unsubstituted product **84**, however, had enantiomeric excess of only 35%, despite originating from epoxide **81** with an enantiomeric excess of 82%.

Regioselectivity in the acid-catalysed ring-opening of **82** is the same as enantiospecificity. Attack at C-3 gives one enantiomer of the diol **83**, while attack at C-2 gives the other. The C-3 selectivity usually observed in these reactions arises from the electron-withdrawing effect of the sulfonate group, which deactivates C-2 toward attack.[27] Our epoxide **82** also has an inductive electron-withdrawing diphenylphosphinoyl group deactivating C-3 (hence its low reactivity under acidic conditions). Moreover, the diphenylphosphinoyl group can



Scheme 9 *Reagents:* A, MsCl, Et_3N; B, $HClO_4$, H_2O, THF, reflux; C, $HClO_4$, H_2O, DMSO, r.t.; D, K_2CO_3, MeOH

Table 3 C-1 Regioselective ring-opening reactions

Entry	Starting material	Reagents*	Product	Nu =	Yield (%)
1	**82**	A	**85**	PhS	82
2	**78**	A	**86**	PhS	96
3	(±)-**78**	B	**87**	*p*-HOC_6H_4S	81
4	(±)-**78**	C	**88**	$Ph(CH_2)_3S$	75
5	(±)-**78**	D	**89**	N_3	97
6	(±)-**78**	1. D; 2. E; 3. F	**90**	NHTs	49
7	(±)-**78**	1. D; 2. E; 3. G	**91**	NHAc	74
8	(±)-**78**	H	**92**	NH_2	100
9	(±)-**78**	1. H; 2. G	**91**	NHAc	81
10	(±)-**78**	I	**93**	5-bromouracil-1-yl	76
11	(±)-**78**	J	**94, 95**	6-chloropurin-9-yl	47
				6-chloropurin-1-yl	12
12	(±)-**78**	K	**96**	CN	92
13	(±)-**78**	1. K; 2. L	**97**	CH_2NHAc	37
14	(±)-**78**	1. K; 2. M	**98**	—	67
15	(±)-**78**	N or O	**72, 73**[a]	—	*b*

* Reagents: A, PhSNa, EtOH; B, *p*-HOC_6H_4SLi, *p*-HOC_6H_4SH, THF; C, $Ph(CH_2)_3SLi$, $Ph(CH_2)_3SH$, THF; D, NaN_3, NH_4Cl; E, H_2, Pd/C; F, TsCl, DMAP; G, Ac_2O; H, NH_3; I, 5-bromouracil, NaH, DMF; J, 6-chloropurine, NaH, DMF; K, (1.) $Yb(CN)_3$, Me_3SiCN; (2.) H_3O^+; L, H_2, PtO_2, Ac_2O; M, H_2, Pd/C, Ac_2O; N, KCN, DMF; O, NaCN, THF. [a] Plus several other unidentified products. [b] Not determined.

hinder attack at C-3 sterically. These two effects combined are known to be more than able to overcome any C-3 selectivity in some reactions.[9] The drop in enantiomeric excess of epoxide **84** from 82 to 35% represents a regioselectivity of 2.5:1. We have assumed that C-3 attack still predominates, though this is not certain. The C-3 selectivity in attack on **75** and **78** is saved by the methyl group, which can stabilise an incipient positive charge on the C-3 carbon, promoting attack at this centre under acid conditions.[29]

The terminal epoxides **70, 80** and **84** were opened with a variety of nucleophiles (Table 3) in order to perform Horner–Wittig eliminations on the β-hydroxy phosphine oxide products. More readily available racemic material was used for most of these reactions.

Thiolate nucleophiles reacted very cleanly with the epoxides **80** and **84** (entries 1–4). Ammonium azide and ammonia also opened the epoxide **80** in excellent yield to give azide **89** and amine **92** (entries 5 and 8). These compounds were conveniently protected as a sulfonamide **90** or an acetamide **91** (entries 6, 7 and 9). The sodium anions of 5-bromouracil and 6-chloropurine[30,31] opened the epoxide **80** successfully (though in moderate yield) to give a pyrimidine **93** and a purine **94** (entries 10 and 11). A significant amount of a regioisomer[31] **95** was also formed in the reaction with **80**.

A nitrile functional group was introduced successfully by using ytterbium(III) cyanide with a trimethylsilyl cyanide buffer (entry 12),[32] and the nitrile **96** was converted into the acetamide **97** by hydrogenation (H_2, PtO_2, Ac_2O) (entry 13). Attempted hydrogenation of the nitrile over 5% Pd–C in acetic anhydride gave, bizarrely, a good yield of the ketone **98** (entry 14). Unbuffered reactions of **80** with cyanide gave a complex mixture of products (entry 15), including the vinyl phosphine oxides **72** and **73**, formed by base-catalysed Payne rearrangement and elimination.

Attempts to make allylic alcohols from the diols that had been produced by the epoxide openings were only partially successful. Several of these diols were treated with an excess of sodium or potassium base under standard conditions for promoting the Horner–Wittig elimination,[1] but only two, the phenyl sulfides **85** and **86**, gave any of the desired elimination products (**99** and **100**), and only in low yield (Scheme 10). The by-products from this reaction, benzenethiol and its oxidation product diphenyl disulfide, suggested that a fragmentation **101** (similar to that observed in the attempted elimination of the ester **64**) was taking place. Attempted elimination of the acetamide **91** gave another fragmentation *via* **102**, and methyldiphenylphosphine oxide was isolated in 59% yield. This reaction was noted above in the attempted elimination of another tertiary alcohol **16**. None of the number of other conditions which were tried with this compound gave the desired Horner–Wittig elimination product.

Experimental

Flash chromatography refers to chromatography on silica by the method of Still, Kahn and Mitra.[33] Values of coupling constants (J) are given in Hz and $[\alpha]_D$ values in 10^{-1} deg cm^2 g^{-1}. Unless an enantiomeric excess and specific rotation are quoted for the product, starting epoxides are racemic; enantiomeric excesses were determined using 1-(9-anthryl)-2,2,2-trifluoroethanol.[6,24] In certain cases, the Attached Proton Test (APT) was applied to ^{13}C NMR spectra. Positive peaks in the APT are indicated by $^+$, negative ones by $^-$.

Attack of PhSLi on epoxide 1a

Butyllithium (1.5 mol dm^{-3} solution in hexane; 0.5 cm^3, 0.78 mmol) was added dropwise to a stirred solution of the epoxide[6] **1a** (120 mg, 0.45 mmol) and benzenethiol (0.5 cm^3, 4.9 mmol) in THF (5 cm^3) at 20 °C under nitrogen. After being stirred for 1 h the mixture was diluted with diethyl ether (10 cm^3) and washed with 3% aqueous sodium hydroxide (2 × 5 cm^3) and water (2 × 5 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give an oil, which was purified by chromatography on a short fat column of silica, eluting with EtOAc. The two components of the mixture were separated by HPLC, eluting with EtOAc–15% hexane to give (2RS,3SR)-1-*diphenylphosphinoyl*-3-*phenylsulfanylbutan*-2-*ol* **6** (36 mg, 21%) as an oil, R_F(EtOAc) 0.42 (Found: $M^+ - SPh - MeCHOH$, 255.0938. $C_{16}H_{16}OP$ requires 255.0925); $\nu_{max}(CHCl_3)/cm^{-1}$ 3400 (OH), 1437 (PPh) and 1178 (P=O); δ_H(250 MHz; $CDCl_3$) 7.9–7.3 (10 H, m, Ph_2PO), 7.2 (5 H, m, PhS), 4.05 (1 H, br s, CHO*H*), 4.2–3.8 (1 H, m, C*H*OH), 3.27 (1 H, dq, J 6.5 and 6, SCH), 2.82 (1 H, ddd, J 16, 9 and 3, PCH_AH_B), 2.46 (1 H, ddd, J 16, 12.5 and 9.5, PCH_AH_B) and 1.28 (3 H, d, J 6, *Me*CH); δ_C(100 MHz; $CDCl_3$) 134–127 (Ph_2PO and PhS), 70 (J_{PC} 3.5, CHOH), 50 (J_{PC} 12, CHS), 34 (J_{PC} 71, PCH_2) and 16.4 (Me); m/z 255 (100%, M − SPh − H_2O) and 201 (99, Ph_2PO).

Also obtained was (2RS,3RS)-4-*diphenylphosphinoyl*-3-*phenylsulfanylbutan*-2-*ol* **5** (78 mg, 46%) as an oil, R_F(EtOAc) 0.34 (Found: $M^+ - H$, 381.1060. $C_{22}H_{22}O_2P$ requires

381.1076); $\nu_{max}(CHCl_3)/cm^{-1}$ 3450 (OH), 1440 (PPh) and 1178 (P=O); δ_H(250 MHz; $CDCl_3$) 7.8–7.3 (10 H, m, Ph_2PO), 7.2 (5 H, m, PhS), 4.3 (1 H, br s, CHO*H*), 3.94 (1 H, q, *J* 6, C*H*OH), 3.04 (1 H, dq, *J* 12 and 6, SCH), 2.9–2.6 (2 H, m, CH_2P) and 1.31 (3 H, d, *J* 6, *Me*CH); δ_C(100 MHz; $CDCl_3$) 134–127 (Ph_2PO and PhS), 70 (J_{PC} 2.3, CHOH), 52 (J_{PC} 3.7, CHS), 34 (J_{PC} 65, PCH_2) and 21.5 (Me); *m/z* 381 (0.3%, M − H) and 202 (100, Ph_2POH).

Attack of $Ph(CH_2)_3SLi$ on the epoxide 1b

Butyllithium (1.5 mol dm^{-3} solution in hexane; 0.3 cm^3, 0.46 mmol) was added dropwise to a stirred solution of $Ph(CH_2)_3SH$ (0.1 cm^3, 0.66 mmol) in THF (2 cm^3) at 0 °C under nitrogen and stirring was continued for 5 min. The epoxide[6] **1b** (93 mg, 0.25 mmol) was added in one portion to the above solution and the resulting mixture was allowed to warm to room temperature over 15 min. It was then applied directly to two PLC plates (SiO_2–EtOAc: 50% hexane) to give (2RS,3SR,4SR,5SR)-5-*diphenylphosphinoyl*-4-(3-*phenylpropylsulfanyl*)*decane*-2,3-*diol* **7** (78 mg, 60%) as a white crystalline solid, mp 133–133.5 °C (from EtOAc–hexane) (Found: M^+ − MeCHOH, 479.2188. $C_{29}H_{36}O_2PS$ requires 479.2173); $\nu_{max}(CHCl_3)/cm^{-1}$ 3200 (OH), 1440 (PPh) and 1150 (P=O); δ_H(250 MHz; $CDCl_3$) 7.0–8.0 (15 H, m, Ph_2PO + Ph), 6.45 (1 H, d, *J* 4, SCHCHO*H*), 4.08 (1 H, q, *J* 6, MeC*H*OH), 3.44 (1 H, dd, *J* 9 and 4, SCHC*H*OH), 3.10 (1 H, dd, *J* 13 and 9, SCH), 2.95 (1 H, m, PCH), 2.55 and 2.38 (4 H, 2 × t, *J* 7 Hz, $SCH_2CH_2CH_2$), 2.2–1.0 [11 H, m, $(CH_2)_4$ + SCH_2CH_2 + OH], 1.28 (3 H, d, *J* 6, *Me*CH) and 0.78 (3 H, t, *J* 7, CH_3CH_2). Addition of D_2O caused the signal at δ 6.45 to disappear and the signal at δ 8.34 to simplify to (1 H, d, *J* 9); δ_C(100 MHz; $CDCl_3$) 13.8 (q, CH_3CH_2), 21.3 (q, CH_3CH), 22.1 (t, $MeCH_2$), 24.7 (t, $MeCH_2CH_2$), 29.7 (dt, J_{PC} 9, $PCHCH_2CH_2$), 30.9 and 31.7 (2 C, 2 × t, $PCHCH_2$ + SCH_2CH_2), 33.2 (t, $PhCH_2$), 34.8 (t, SCH_2), 45.1 (dd, J_{PC} 61.5, PCH), 47.2 (d, SCH), 67.6 and 74.4 (2 C, 2 × d, 2 × CHOH) and 128.0–133.0 (18 C, m, Ph_2PO + Ph); *m/z* 479 (38%, M − MeCHOH), 450 (7), 299 (270) and 202 (100, Ph_2POH).

Attack of $Ph(CH_2)_3SNa$ on the epoxide *anti,syn*-1b

Sodium hydride (50% dispersion in mineral oil; 13 mg, 0.16 mmol) was added in one portion to a stirred solution of $Ph(CH_2)_3SH$ (0.1 cm^3, 0.65 mmol) in THF (2 cm^3) at room temperature under nitrogen. After the evolution of gas had ceased, the epoxide[6] *anti,syn*-**1b** (100 mg, 0.27 mmol) was added to the solution and stirring was continued for 1 h. The reaction mixture was applied directly to two PLC plates (SiO_2, EtOAc–50% hexane) to give the diol **7** (93 mg, 66%).

Attack of PhSNa on the epoxide 1c

Benzenethiol (0.1 cm^3, 1.0 mmol, 6 equiv.) and sodium benzenethiolate (23.0 mg, 0.174 mmol, 1.06 equiv.) were added to a stirred solution of the epoxy alcohol[6] **1c** (35.9 mg, 0.119 mmol) in dry ethanol (1 cm^3). After 74 h, the solvent was removed under reduced pressure from the mixture and the residue was dissolved in ethyl acetate. The solution was washed with dilute aqueous sodium hydroxide (× 2) and water (× 2), dried (Na_2SO_4), and evaporated under reduced pressure to give (2*R*,3*S*)-4-diphenylphosphinoyl-3-methyl-2-phenylsulfanylbutane-1,3-diol **8** (62.7 mg, 100%) as an oil, $[\alpha]_D^{25}$ +37.0 (*c* 1.41 in $CHCl_3$; 97% ee); R_F(EtOAc) 0.46; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3100 (OH), 1440 (PPh) and 1150 (P=O); δ_H(250 MHz; $CDCl_3$) 7.8–7.1 (15 H, m, Ph_2PO and PhS), 4.09 (1 H, dd, *J* 12.1 and 9.0, CH_AH_BOH), 3.72 (1 H, dd, *J* 12.1 and 3.7, CH_AH_BOH), 3.51 (1 H, dd, *J* 9.0 and 3.7, CHS), 3.03 (2 H, ABP m, PCH_2) and 1.39 (3 H, s, Me); δ_C(100 MHz; $CDCl_3$) 137–126 (Ph_2PO and PhS), 77.3$^-$ (MeCOH), 63.3$^-$ (CH_2OH), 58.1$^+$ ($^3J_{PC}$ 8.0, CHS), 39.2$^-$ ($^1J_{PC}$ 68.7, PCH_2) and 25.1$^+$ ($^3J_{PC}$ 7.0, Me); *m/z* 285 (32%, M − SPh − H_2O), 259 [56, $Ph_2POCH_2C(OH)Me$], 218 (37, Ph_2PO_2H), 216 (31, Ph_2POMe), 215 (Ph_2POCH_2), 202 (21, Ph_2POH) and 201 (100, Ph_2PO).

Attack of PhSLi on the epoxide *anti*-1d

Butyllithium (1.5 mol dm^{-3} solution in hexane; 0.35 cm^3, 0.5 mmol) was added dropwise to a stirred solution of benzenethiol (220 mg, 2.0 mmol) in THF (1.5 cm^3) at 20 °C under nitrogen. This solution was, in turn, added dropwise to a stirred solution of the epoxide[6] *anti*-**1d** (120 mg, 0.34 mmol) in THF (1.5 mmol) and heated at 45 °C for 24 h. After cooling, the mixture was diluted with diethyl ether (10 cm^3) washed with 3% aqueous sodium hydroxide (2 × 5 cm^3) and water (2 × 5 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give an oil. This was purified by chromatography on a short fat column of silica, eluting with EtOAc. The two components of the mixture were separated by HPLC, eluting with Et_2O–50% CH_2Cl_2 to give (3RS,4RS,5RS)-5-*diphenylphosphinoyl*-4-*methyl*-4-(*phenylsulfanyl*)*decan*-3-*ol* **9** (40 mg, 25%) as an oil, R_F(EtOAc) 0.57 (Found: M^+ − H, 479.2150. $C_{29}H_{36}O_2PS$ requires 479.2174); δ_H(250 MHz; $CDCl_3$) 7.8–7.2 (15 H, m, Ph_2PO and PhS), 6.3 (1 H, br s, OH), 3.7 (1 H, dd, *J* 8 and 2, C*H*OH), 2.65 (1 H, ddd, *J* 8, 7 and 3, SCH), 2.3–0.5 (16 H, m), 1.1 (3 H, s, MeCS) and 0.65 (3 H, t, *J* 6, *Me*CH_2CH_2); *m/z* 479 (0.04%, M − H), 371 (8, M − SPh), 353 (10, M − SPh − OH) and 202 (100, Ph_2PO).

Also obtained was (3RS,4SR,5SR)-5-*diphenylphosphinoyl*-4-*methyl*-3-(*phenylsulfanyl*)*decan*-4-*ol* **10** (60 mg, 37%) as a solid, R_F(EtOAc) 0.49 (Found: C, 72.4; H, 7.97%; M^+ − Me, 465.2003. $C_{29}H_{37}O_2PS$ requires C, 72.5; H, 7.71%; M^+ − Me, 465.2107); δ_H(250 MHz; $CDCl_3$) 8.1–7.1 (15 H, m, Ph_2PO and PhS), 3.7 (1 H, br s, OH), 3.30 (1 H, dd, *J* 9 and 2, CHS), 3.0 (1 H, m, PCH_2), 2.5–0.5 (10 H, m), 1.21 (3 H, s, MeCO) and 0.8–0.4 (6 H, m, *Me*CH_2 × 2); *m/z* 465 (13%, M − Me), 353 (32, M − SPh − OH), 329 (90, M − C_3H_6SPh), 286 (10, M − C_5H_9OSPh) and 201 (100, Ph_2PO).

Attack of PhSNa on the epoxy alcohol *anti*-1e

Benzenethiol (0.1 cm^3, 0.98 mmol, 6.4 equiv.) and sodium benzenethiolate (24 mg, 0.18 mmol, 1.2 equiv.) were added to a solution of the epoxy alcohol[6] *anti*-**1e** (49.9 mg, 0.151 mmol) in dry ethanol (1 cm^3). The mixture was stirred at room temperature for 94 h, when TLC showed almost complete consumption of starting material. After being heated under reflux for a further 28 h, the mixture was diluted with chloroform, washed with dilute aqueous sodium hydroxide, water and brine, dried (Na_2SO_4) and evaporated under reduced pressure. Purification of the residue by flash chromatography, eluting with EtOAc–hexane (3:2) and then EtOAc–hexane (4:1), gave oily material (11.7 mg, 18%), tentatively identified by ^1H NMR spectroscopy as (2*S*,3*S*,4*R*)-4-diphenylphosphinoyl-5-methyl-2-(phenylsulfanyl)hexane-1,3-diol **11**; R_F(EtOAc) 0.50; δ_H(250 MHz; $CDCl_3$) 8.0–7.1 (15 H, m, Ph_2PO and PhS), 4.24 (1 H, t, *J* 10.3, C*H*OH), 3.77 (2 H, ABX m, CH_2OH), 3.54 (1 H, dt, *J* 10.8 and 5.7, CHS), 3.09 (1 H, d, *J* 9.1, PCH), 2.42 (1 H, d × octet, *J* 14.0 and 7.0, $CHMe_2$), 1.20 (3 H, d, *J* 6.8, $CHMe_AMe_B$) and 0.88 (3 H, d, *J* 6.8, $CHMe_AMe_B$).

Attack of NH_4N_3 on the epoxy alcohol *anti*-1e

A solution of sodium azide (100 mg, 1.5 mmol, 5.4 equiv.) and ammonium chloride (36 mg, 0.67 mmol, 2.3 equiv.) in water (0.25 cm^3) was added at room temperature to a solution of the epoxy alcohol[6] *anti*-**1e** (94.9 mg, 0.287 mmol) in 2-methoxyethanol (2 cm^3). The mixture was heated under reflux (135 °C) for 4 days and then cooled and concentrated under reduced pressure. The residue was purified by flash chromatography, eluting with EtOAc–hexane (4:1), then EtOAc, and then EtOAc–10% MeOH, to give crystalline material (14.2 mg, 13%), tentatively

identified by ^{1}H NMR spectroscopy as (2*S*,3*S*,4*R*)-2-azido-4-diphenylphosphinoyl-5-methylhexane-1,3-diol **13**, R_F(EtOAc) 0.45; δ_H(250 MHz; $CDCl_3$) 7.9–7.4 (10 H, m, Ph_2PO), 4.29 (1 H, t, *J* 10.4, C*H*OH), 4.17 (1 H, dd, *J* 12.0 and 3.1, CH_AH_BOH), 3.98 (1 H, dd, *J* 12.1 and 3.4, CH_AH_BOH), 3.54 (1 H, dt, *J* 10.8 and 3.0, CHN_3), 2.81 (1 H, d, *J* 9.2, PCH), 2.34 (1 H, d × octet, *J* 14.0 and 7.0, C*H*Me_2), 1.21 (3 H, d, *J* 6.8, CH*Me*$_A$Me$_B$) and 0.93 (3 H, d, *J* 6.8, CHMe$_A$*Me*$_B$).

Also obtained was an oil (9.4 mg, 9%), tentatively identified by its ^{1}H NMR spectrum as (2*S*,3*R*,4*R*)-3-azido-4-diphenylphosphinoyl-5-methylhexane-1,3-diol **12**; R_F(EtOAc) 0.35; δ_H(250 MHz; $CDCl_3$) 7.9–7.4 (10 H, m, Ph_2PO), 3.91 (1 H, dd, *J* 13.8 and 6.1, CHN_3), 3.73 (2 H, m, CH_AH_BOH and C*H*OH), 3.59 (1 H, dd, *J* 12.3 and 4.8, CH_AH_BOH), 3.05 (1 H, d, *J* 15.0, PCH), 2.3 (1 H, m, C*H*Me_2), 1.10 (3 H, d, *J* 6.8, CH*Me*$_A$Me$_B$) and 0.86 (3 H, d, *J* 6.8, CHMe$_A$*Me*$_B$).

Attack of the Na salt of thymine on epoxy alcohol *anti*-1e

Sodium hydride (80% suspension; 13.1 mg, 0.44 mmol, 1.6 equiv.) was added to a stirred solution of thymine (108 mg, 0.86 mmol, 3.2 equiv.) in dry DMSO (1 cm^3) under nitrogen. After 40 min, the mixture had cleared, and a solution of the epoxy alcohol[6] *anti*-**1e** (90.1 mg, 0.27 mmol) in dry DMSO (1.5 cm^3) was added to it. After the solution had been stirred at 90 °C for 47 h it was diluted with brine (30 cm^3) and extracted with ethyl acetate (10 cm^3 × 5). The combined extracts were washed with water (10 cm^3 × 2), dried (Na_2SO_4) and evaporated to yield (S,E)-4-*diphenylphosphinoyl*-5-*methylhex*-3-*ene*-1,2-*diol* **14** (71.7 mg, 66%) as an oil (Found: M$^+$, 330.1373. $C_{19}H_{23}O_3P$ requires *M*, 330.1385); R_F($CHCl_3$ – 10% MeOH – 2% NH_3) 0.28; ν_{max}($CHCl_3$)/cm^{-1} 3600–3200 (OH), 1430 (PPh) and 1160 (P=O); δ_H(250 MHz; $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 5.93 (1 H, dd, *J* 23.5 and 8.5, C=CH), 4.76 (1 H, m, C*H*OH), 4.15 (1 H, br s, OH), 3.95 (1 H, br s, OH), 3.64 (1 H, dd, *J* 11.0 and 2.5, CH_AH_BOH), 3.47 (1 H, dd, *J* 11.0 and 7.5, CH_AH_BOH), 2.84 (1 H, d × septet, *J* 14.0 and 7.0, C*H*Me_2), 1.15 (3 H, d, *J* 7.0, CH*Me*$_A$Me$_B$) and 1.11 (3 H, d, *J* 7.0, CHMe$_A$*Me*$_B$); δ_C(100 MHz; $CDCl_3$) 144.3$^+$ ($^2J_{PC}$ 10.2, PC=C), 141.8$^+$ ($^1J_{PC}$ 90.3, PC), 133-128 (Ph_2PO), 69.6$^+$ ($^3J_{PC}$ 17.4, CHOH), 66.0$^-$ ($^4J_{PC}$ 1.4, CHOH), 29.9$^+$ ($^2J_{PC}$ 10.2, $CHMe_2$), 23.0$^+$ ($^3J_{PC}$ 3.6, CH*Me*$_A$Me$_B$) and 22.3$^+$ ($^3J_{PC}$ 3.7, CHMe$_A$*Me*$_B$); *m*/*z* 330 (3.5%, M$^+$), 312 (45, M – H_2O), 299 (39, M – CH_2OH), 283 (42), 225 (34), 202 (77, Ph_2POH) and 201 (100, Ph_2PO).

Me_3Al-Catalysed addition of PhSH to the epoxide *anti*-1d

A solution of benzenethiol (0.64 cm^3, 6.25 mmol) in dichloromethane (3 cm^3) was added dropwise to trimethylaluminium (2.5 mol dm^{-3} solution in THF; 2.5 cm^3, 6.25 mmol) at 0 °C under nitrogen and the mixture stirred for 10 min. A solution of the epoxide[6] *anti*-**1d** (278 mg, 0.75 mmol) in dichloromethane (3 cm^3) was added to the mixture which was then warmed to room temperature for 16 h. After dilution with water (25 cm^3) the mixture was extracted with dichloromethane (3 × 15 cm^3). The combined extracts were washed with aqueous sodium hydroxide (2 mol dm^{-3}; 10 cm^3) and water (2 × 10 cm^3), dried (Na_2SO_4) and evaporated under reduced pressure to give an oil consisting (by NMR) only of regioisomer **10** (>6:1 **10**:**9**). Flash chromatography of the oil gave the alcohol **10** (210 mg, 59%).

Me_3Al-Catalysed addition of $Ph(CH_2)_3SH$ to the epoxide *syn,syn*-1f

$Ph(CH_2)_3SH$ (0.4 cm^3, 2.6 mmol) was added dropwise to a stirred solution of trimethylaluminium (2.5 mol dm^{-3} solution in THF; 1.05 cm^3, 2.6 mmol) at 0 °C under nitrogen and the resulting mixture was allowed to warm to room temperature over 10 min. After this a solution of the epoxy alcohol[6] **1f** (0.768 g, 2 mmol) in dichloromethane (2 cm^3) was added dropwise to the mixture and stirring was continued for 48 h. A second portion of a mixture of $Ph(CH_2)_3SH$ (0.4 cm^3) and trimethylaluminium (1.05 cm^3) was added to the reaction mixture and stirring continued for a further 48 h at room temperature. The resulting solution was then poured into sat. aq. NH_4Cl (50 cm^3) and extracted with dichloromethane (3 × 30 cm^3). The combined extracts were dried (Na_2SO_4) and evaporated under reduced pressure to give an oil. Purification of this crude product by flash chromatography (SiO_2, EtOAc–40% hexane followed by EtOAc) gave recovered epoxy alcohol **1f** (173 mg, 23%).

Also obtained was (2*RS*,3*SR*,4*SR*,5*RS*)-5-diphenylphosphinoyl-4-methyl-4-(3-phenylpropylsulfanyl)decane-2,3-diol **15** (122 mg, 11%) as an oil, R_F(EtOAc–40% hexane) 0.28 (Found: M$^+$ – MeCHOH, 493.2328. $C_{30}H_{38}O_2PS$ requires *M* – MeCHOH, 493.2330); ν_{max}($CHCl_3$)/cm^{-1} 3400 (OH), 1440 (P–Ph) and 1150 (P=O); δ_H(250 MHz; $CDCl_3$) 0.70 (3 H, t, *J* 7, CH_3CH_2) 0.8–3.0 (16 H, m), 1.19 (3 H, d, *J* 6, CH_3CH), 1.40 (3 H, s, MeCS), 3.66 [1 H, d, *J* 6, C*H*(OH)CS], 4.30 (1 H, q, *J* 6, MeC*H*OH), 6.0 (1 H, d, *J* 6, SCCHO*H*) and 7.1–8.1 (10 H, m, Ph_2PO). Addition of D_2O caused the signal at δ 6.0 to disappear and the signal at δ 3.66 to simplify to a singlet; *m*/*z* 493 (35%, M – MeCHOH), 464 [28, M – MeCH(OH)CHO], 430 (12), 202 (100, Ph_2POH) and 201 (78, Ph_2PO).

Also obtained was (2*RS*,3*RS*,4*SR*,5*RS*)-5-diphenylphosphinoyl-4-methyl-3-(3-phenylpropylsulfanyl)decane-2,4-diol **16** (168 mg, 16%) as an oil, R_F(EtOAc–40% hexane) 0.21 (Found: M$^+$ – MeCHOH – OH, 476.2290. $C_{30}H_{37}OPS$ requires *M* – MeCHOH–OH, 476.2303); ν_{max}($CHCl_3$)/cm^{-1} 3400 (OH), 1437 (P-Ph) and 1163 (P=O); δ_H(250 MHz; $CDCl_3$) 0.72 (3 H, t, *J* 6, CH_3CH_2) 0.85–2.4 (13 H, m), 1.30 (3 H, d, *J* 6, CH_3CH), 1.41 (3 H, s, MeC), 2.57 (2 H, t, *J* 7, $PhCH_2$), 3.10 (1 H, d, *J* 8, SCH), 4.20 (1 H, distorted quintet, *J* 7, C*H*OH), 4.7 and 6.4 (2 H, 2 × broad s, 2 × OH) and 7.1–8.1 (10 H, m, Ph_2PO). Irradiation of the signal at δ 4.20 caused the signal at δ 1.30 to simplify to a singlet and addition of D_2O caused the disappearance of the signals at δ 4.7 and 6.4; *m*/*z* 476 (5%), 419 (4), 401 (9), 369 [43, M – $Ph(CH_2)_3SH$ – H_2O], 329 (100), 286 (15), 229 (41, $Ph_2PO_2H_2$), 202 (80, Ph_2POH) and 201 (94, Ph_2PO).

Me_3Al-Catalysed addition of $Ph(CH_2)_3SH$ to the epoxide *anti,syn*-1b

Trimethylaluminium (2.5 mol dm^{-3} solution in THF; 1.2 cm^3, 3 mmol) was added dropwise to a stirred solution of the epoxy alcohol[6] *anti,syn*-**1b** (0.5 g, 1.34 mmol) and $Ph(CH_2)_3SH$ (0.5 g, 3.2 mmol) in dichloromethane at room temperature under nitrogen and the resulting solution was heated at reflux for 10 h. After cooling, the reaction mixture was poured into 2 mol dm^{-3} aq. NaOH (100 cm^3) and extracted with ether (150 cm^3). The ether layer was washed with 2 mol dm^{-3} aq. NaOH (50 cm^3) and water (50 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give an oil. Purification of this crude product by flash chromatography (SiO_2, EtOAc–65% hexane) gave 5-*diphenylphosphinoyl*-2-(3-*phenylpropylsulfanyl*)*decane*-3,4-*diol* **29** (73 mg, 10%) as a white crystalline solid, mp 133–135 °C; R_F(EtOAc–hexane) 0.29 (Found: M$^+$ – H_2O, 506.2410. $C_{31}H_{39}O_2PS$ requires M^+ – H_2O, 506.2408); ν_{max}($CHCl_3$)/cm^{-1} 3350 (OH), 1590 and 1600 (Ph), 1442 (P–Ph) and 1660 (P=O); δ_H(250 MHz; $CDCl_3$) 0.77 (3 H, t, *J* 7, CH_3CH_2), 1.0–1.7 [8 H, m, $(CH_2)_4$], 1.31 (3 H, d, *J* 6), 1.84 (2 H, qn, *J* 7.5, CH_2CH_2S), 2.51 and 2.67 (5 H, m, $CH_2CH_2CH_2$ and PCH), 2.73 (1 H, m, SCH), 3.74 (1 H, dt, *J* 25 and 2, PCHC*H*OH), 7.0–7.3 (5 H, m, *Ph*CH_2) and 7.3–8.0 (10 H, m, Ph_2PO). Irradiation of the signal at δ 1.31 or 3.74 simplified the signal at δ 2.73; *m*/*z* 506 (11%, M – H_2O), 355 [38, M – $Ph(CH_2)_3S$ – H_2O], 345 [72, M – $Ph(CH_2)_3SCHMe$], 316 [11, M – $Ph(CH_2)_3SCH$-(Me)CHO], 315 [19, M – $Ph(CH_2)_3SCH(Me)CHOH$], 229

[22, $Ph_2P(OH)CHCH_2$], 219 (14, $Ph_2PO_2H_2$), 202 (100, Ph_2POH) and 201 (Ph_2PO).

Also obtained was the diol **7** (65 mg, 9%) as a white crystalline solid, R_F(EtOAc–66% hexane) 0.21, and (2RS, 3SR,4SR,5SR)-5-*diphenylphosphinoyl*-3-(3-*phenylpropylsulfanyl*)*decane*-2,4-*diol* **17** (219 mg, 31%) as an oil, R_F(EtOAc–66% hexane) 0.17 (Found: $M^+ - 2H_2O$, 488.2303. $C_{31}H_{37}OPS$ requires $M^+ - 2H_2O$, 488.2303); $\nu_{max}(CHCl_3)/cm^{-1}$ 3400 (OH), 1600 and 1590 (C=C), 1442 (P–Ph) and 1163 (P=O); δ_H(250 MHz; $CDCl_3$ + D_2O) 0.69 (3 H, t, *J* 7, CH_3CH_2), 0.8–1.9 [8 H, m, $(CH_2)_4$], 1.28 (3 H, d, *J* 6, CH_3CH), 1.86 (2 H, quintet, *J* 7.5, CH_2CH_2S), 2.38 (1 H, dt, J_{AB} 12, J_{AX} 7.5, $PhCH_AH_B$), 2.48 (1 H, dt, J_{AB} 12, J_{BX} 7.5, $PhCH_AH_B$), 2.63 (1 H, t, *J* 8.5, SCH), 2.68 (2 H, t, *J* 7.5, SCH_2), 3.07 (1 H, dt, *J* 3 and Hz, PCH), 3.95–4.2 (2 H, m, 2 × CHOH), 7.0–7.3 (5 H, m, $PhCH_2$) and 7.3–8.0 (10 H, m, Ph_2PO); *m*/*z* 488 (0.065% M – H_2O – H_2O), 355 [12, M – $Ph(CH_2)_3S$ – H_2O], 315 [50, M – $Ph(CH_2)_3SCHCH(OH)Me$], 286 (12), 229 [38, $Ph_2P(OH)CHCH_2$], 202 (72, Ph_2POH) and 201 (100, Ph_2PO).

(2*S*,3*R*,4*R*)-4-Diphenylphosphinoyl-5-methyl-2-(3-phenylpropylsulfanyl)hexane-1,3-diol 18

Trimethylaluminium (2 mol dm^{-3} solution in toluene; 0.84 cm^3, 3.1 equiv.) and $Ph(CH_2)_3SH$ (0.1 cm^3, 0.43 mmol, 1.23 equiv.) were added to a solution of the epoxide[6] *anti*-**1e** (180.2 mg, 0.546 mmol) in dry dichloromethane (5.5 cm^3). The mixture was heated under reflux for 1 h, cooled, carefully quenched with dilute aqueous sodium hydroxide and diluted with dichloromethane. The layers were separated, and the aqueous layer was extracted with dichloromethane (× 2). The combined organic layer and extracts were washed with brine, dried ($MgSO_4$) and evaporated under reduced pressure. Purification of the residue by flash chromatography, eluting with EtOAc–hexane (4:1), gave the *sulfide* **359** (181.2 mg, 69%) as an oil, $[\alpha]_D^{25}$ –7.2 (*c* 0.72 in $CHCl_3$; 85% ee) (Found: M – H_2O, 464.1917. $C_{28}H_{35}O_3PS$ requires *M* – H_2O, 464.1938); R_F(EtOAc) 0.37; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3200 (OH), 1430 (PPh) and 1150 (P=O); δ_H(250 MHz; $CDCl_3$) 8.0–7.1 (15 H, m, Ph_2PO and Ph), 4.11 (1 H, t, *J* 10.6, CHOH), 3.77 (2 H, m, CH_2OH), 3.51 (1 H, dd, *J* 7.8 and 4.8, $CHSCH_2$), 3.1–2.9 (2 H, m, PCH and $CHMe_2$), 2.67 (1 H, t, *J* 7.0, CH_2S), 2.47 (1 H, dt, *J* 12 and 7.5, CH_AH_BPh), 2.32 (1 H, dt, *J* 12 and 7.5, CH_AH_BPh), 1.86 (2 H, quintet, *J* 7.0, $CH_2CH_2CH_2$), 1.20 (3 H, d, *J* 6.8, $CHMe_AMe_B$) and 0.92 (3 H, d, *J* 6.8, $CHMe_AMe_B$); δ_C(100 MHz; $CDCl_3$) 134–126 (Ph_2PO and Ph), 75.4$^+$ (CHOH), 65.7$^-$ (CH_2OH), 48.4$^+$ ($^3J_{PC}$ 12.6, $CHSCH_2$), 43.7$^+$ ($^1J_{PC}$ 67.2, PCH), 34.8$^-$, 31.3$^-$, 29.6$^-$ [$(CH_2)_3$], 26.0$^+$ ($CHMe_2$), 24.7$^+$ ($CHMe_AMe_B$) and 22.1$^+$ ($^3J_{PC}$ 8.7, $CHMe_AMe_B$); *m*/*z* 464 (2%, M – H_2O), 451 (4, M – CH_2OH), 313 [89, M – H_2O – $Ph(CH_2)_3S$], 287 [78, $Ph_2POCH(CHMe_2)CHOH$], 243 (49, $Ph_2POC_3H_6$), 202 (55, Ph_2POH) and 201 (100, Ph_2PO).

(2*S*,3*R*,4*S*)-4-Diphenylphosphinoyl-5-methyl-2-(3-phenylpropylsulfanyl)hexane-1,3-diol 19

In the same way, the epoxy alcohol[6] gave the *sulfide* **19** (77.4 mg, 46%) as an oil, $[\alpha]_D^{25}$ +38.6 (*c* 0.20 in $CHCl_3$; 65% ee). (Found: M – H_2O, 464.1913. $C_{28}H_{35}O_3PS$ requires M – H_2O, 464.1938); R_F(EtOAc) 0.43; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3200 (OH), 1440 (PPh) and 1150 (P=O); δ_H (400 MHz; $CDCl_3$) 8.0–7.1 (15 H, m, Ph_2PO and Ph), 6.35 (1 H, d, *J* 6.9, CHO*H*), 4.07 (1 H, ddd, *J* 23.7, 11.2 and 7.0, CHOH), 3.70 (2 H, m, CH_2OH), 3.53 (1 H, dd, *J* 8.8 and 4.0, CH_2OH), 3.16 (1 H, dd, *J* 10.7 and 1.4, CHP), 2.30 (1 H, ddd, *J* 10.8, 6.6 and 4.0, $CHSCH_2$), 2.21 (1 H, dt, *J* 11.8 and 7.6, CH_AH_BPh), 2.13 (1 H, m, $CHMe_2$), 2.00 (1 H, dt, *J* 11.8 and 7.4, CH_AH_BPh), 1.71 (2 H, quintet, *J* 7.4, $CH_2CH_2CH_2$), 1.11 (3 H, d, *J* 6.9, $CHMe_AMe_B$) and 1.01 (3 H, d, *J* 6.9, $CHMe_AMe_B$); δ_C(100 MHz; $CDCl_3$) 141–126 (Ph_2PO and Ph), 75.6$^+$ ($^2J_{PC}$ 4.7, CHOH), 65.0$^-$ (CH_2OH), 51.3$^+$ ($CHSCH_2$), 42.6$^+$ ($^1J_{PC}$ 65.2, PCH), 34.9$^-$, 31.0$^-$, 29.8$^-$ [$(CH_2)_3$], 28.0$^+$ ($CHMe_2$), 22.7$^+$ ($^3J_{PC}$ 4.2, $CHMe_AMe_B$) and 18.9$^+$ ($CHMe_AMe_B$); *m*/*z* 464 (0.3%, M – H_2O), 313 [16, M – H_2O – $Ph(CH_2)_3S$], 287 [98, $Ph_2POCH(CHMe_2)CHOH$], 243 (20, $Ph_2POC_3H_6$), 202 (32, Ph_2POH) and 201 (100, Ph_2PO).

Attack of 1,1-dimethylethanethiol on the epoxy alcohol *syn*-1e under Me_3Al catalysis

Similarly, the epoxy alcohol *syn*-**1e** (193 mg, 0.584 mmol) and 1,1-dimethylethanethiol (0.08 cm^3, 0.71 mmol, 1.2 equiv.) gave, after being heated under reflux for 1 h, and purification by flash chromatography, eluting with EtOAc, (2S,3R,4S)-4-*diphenylphosphinoyl*-2-(1,1-*dimethylethylsulfanyl*)-5-*methylhexane*-1,3-*diol* **20** (14.7 mg, 6%) as an oil, $[\alpha]_D^{25}$ +4.3 (*c* 1.00 in $CHCl_3$; 65% ee) (Found: M – Me_3C, 363.1198. $C_{23}H_{33}O_3PS$ requires *M* – Me_3C, 363.1183); R_F(EtOAc) 0.36; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3100 (OH), 1440 (PPh) and 1150 (P=O); δ_H(400 MHz; $CDCl_3$) 7.9–7.4 (10 H, m, Ph_2PO), 3.99 (1 H, dd, *J* 20.9 and 10.7, CHOH), 3.95 (1 H, dd, *J* 11.8 and 3.0, CH_AH_BOH), 3.67 (1 H, dd, *J* 11.7 and 7.1, CH_AH_BOH), 3.18 (1 H, d, *J* 12.5, CHP), 2.83 (1 H, ddd, *J* 10.2, 7.0 and 2.9, $CHSCH_2$), 2.17 (1 H, d × septet, *J* 1.0 and 6.8, $CHMe_2$), 1.13 (9 H, s, Me_3C), 0.89 (3 H, d, *J* 6.8, $CHMe_AMe_B$) and 0.77 (3 H, d, *J* 6.9, $CHMe_AMe_B$); δ_C(100 MHz; $CDCl_3$) 132–126 (Ph_2PO), 73.1$^+$ (CHOH), 65.9$^-$ (CH_2OH), 48.4$^+$ (CHS), 44.8$^+$ ($^1J_{PC}$ 69.2, PCH), 43.6$^-$ (CMe_3), 31.7$^+$ (CMe_3), 28.2$^+$ ($CHMe_2$), 23.2$^+$ ($^3J_{PC}$ 14.1, $CHMe_AMe_B$) and 18.9$^+$ ($CHMe_AMe_B$); *m*/*z* 363 (6%, M – CMe_3), 345 (7.5, M – CMe_3 – H_2O), 313 (7, M – Me_3CS – H_2O), 287 [78, $Ph_2POCH(CHMe_2)CHOH$], 243 (18, $Ph_2POC_3H_6$), 219 (8, $Ph_2PO_2H_2$), 202 (35, Ph_2POH) and 201 (100, Ph_2PO).

Also obtained was (2R,3R,4S)-4-*diphenylphosphinoyl*-2,5-*dimethylhexane*-1,3-*diol* **21** (103.3 mg, 51%) as minute needles, mp 123–125 °C (from EtOAc–MeOH), $[\alpha]_D^{25}$ +18.0 (*c* 0.78 in $CHCl_3$; 65% ee) (Found: M + H, 347.1787. $C_{20}H_{27}O_3P$ requires M + H, 347.1776); R_F(EtOAc) 0.25; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3100 (OH), 1440 (PPh) and 1150 (P=O); δ_H(400 MHz; $CDCl_3$) 7.9–7.4 (10 H, m, Ph_2PO), 3.98 (1 H, dd, *J* 22.2 and 10.0, CHOH), 3.52 (1 H, dd, *J* 11.7 and 7.8, CH_AH_BOH), 3.47 (1 H, dd, *J* 11.7 and 4.1, CH_AH_BOH), 2.46 (1 H, d, *J* 11.2, CHP), 2.14 (1 H, dd × quintet, *J* 11.6, 2.4 and 6.9, $HOCH_2CHMe$), 1.43 (1 H, d × septet, *J* 4.2 and 6.9, $CHMe_2$), 1.12 (3 H, d, *J* 6.9, $CHMe_AMe_B$), 1.00 (3 H, d, *J* 6.7, $HOCH_2CHMe$) and 0.62 (3 H, d, *J* 6.8, $CHMe_AMe_B$); δ_C(100 MHz; $CDCl_3$) 132–128 (Ph_2PO), 76.3$^+$ ($^2J_{PC}$ 5.2, CHOH), 67.7$^-$ (CH_2OH), 44.1$^+$ ($^1J_{PC}$ 69.3, PCH), 39.3$^+$ ($HOCH_2CHMe$), 27.8$^+$ ($CHMe_2$), 23.0$^+$ ($^3J_{PC}$ 15.4, $CHMe_AMe_B$) and 18.7$^+$ and 14.3$^+$ ($CHMe_AMe_B$ and $HOCH_2CHMe$); *m*/*z* 347 (2%, M + H), 287 (80, $Ph_2POC_5H_{10}O$), 219 (8, $Ph_2PO_2H_2$) and 202 (100, Ph_2POH).

Irradiation of the signal at δ 1.00 in the ^1H NMR spectrum resulted in simplification of the signal at δ 2.14. Similarly, irradiation at δ 0.62 simplifies the signal at δ 1.43.

Attack of trimethylaluminium on the epoxy alcohol *syn*-1e

Similarly, the epoxy alcohol[6] *syn*-**1e** (106 mg, 0.321 mmol), with trimethylaluminium (2 mol dm^{-3} solution in toluene; 0.51 cm^3, 1.02 mmol, 3.2 equiv.) but no thiol, gave, after refluxing for 20 h, and purification by flash chromatography, eluting with EtOAc–2.5% MeOH, the diol **21** (68.7 mg, 62%).

(2*S*,3*S*,4*S*)-2-Azido-4-diphenylphosphinoyl-5-methylhexane-1,3-diol 22

Trimethylsilyl azide (90%; 0.10 cm^3, 0.68 mmol, 3.6 equiv.) and titanium tetraisopropoxide (0.10 cm^3, 0.34 mmol, 1.8 equiv.) were added to a solution of the epoxy alcohol[6] *syn*-**1e** (63.0 mg, 0.191 mmol) in dry benzene (2 cm^3). The yellow mixture was heated under reflux for 3 h, concentrated, diluted with dichloromethane, and stirred vigorously with dilute hydrochlo-

ric acid for 1 h. Water (10 cm^3) was added to the mixture which was then extracted with dichloromethane (× 3). The combined extracts were washed with brine, dried ($MgSO_4$) and evaporated under reduced pressure. Purification of the residue by flash chromatography, eluting with EtOAc, gave the *azide* **22** (43.4 mg, 61%) as a powder, mp 136–138 °C (from EtOAc–MeOH), $[\alpha]_D^{25}$ +21.0 (*c* 0.2 in $CHCl_3$; 65% ee) (Found: M + H, 374.1623. $C_{19}H_{24}N_3O_3P$ requires *M* + H, 374.1633); R_F(EtOAc) 0.52; $\nu_{max}(CDCl_3)/cm^{-1}$ 3300 (OH), 2110 (N_3), 1440 (PPh) and 1150 (P=O); δ_H(250 MHz; $CDCl_3$) 8.0–7.4 (10 H, m, Ph_2PO), 6.05 (1 H, d, *J* 7.6, CHO*H*), 4.02 (1 H, dd, *J* 15.2 and 7.2, C*H*OH), 3.88 (1 H, dd, *J* 11.6 and 4.5, CH_AH_BOH), 3.77 (1 H, dd, *J* 11.7 and 4.4, CH_AH_BOH), 2.89 (1 H, dt, *J* 9.9 and 4.7, CHN_3), 2.75 (1 H, dd, *J* 10.2 and 2.0, CHP), 2.1 (1 H, m, $CHMe_2$), 1.12 (3 H, d, *J* 6.9, $CHMe_AMe_B$) and 1.01 (3 H, d, *J* 6.9, $CHMe_AMe_B$); δ_C(100 MHz; $CDCl_3$) 134–128 (Ph_2PO), 71.2$^+$ ($^2J_{PC}$ 5.2, CHOH), 64.6$^+$ (CHN_3), 64.0$^-$ (CH_2OH), 41.7$^+$ ($^1J_{PC}$ 65.8, PCH), 28.0$^+$ ($CHMe_2$), 22.7$^+$ ($^3J_{PC}$ 13.8, $CHMe_AMe_B$) and 19.2$^+$ ($CHMe_AMe_B$); *m*/*z* 374 (1%, M + H), 287 (100, M − CH_2OHCHN_3), 202 (30, Ph_2POH) and 201 (100, Ph_2PO).

Increasing the polarity of the eluent to EtOAc–10% MeOH gave starting material *syn*-**1e** (16.0 mg, 25%).

Attack of trimethylsilyl azide on the epoxy alcohol *anti*-1g

In the same way, the epoxy alcohol[6] *anti*-**1g** (67.8 mg, 0.214 mmol) gave, after being heated under reflux for 4 h, and after purification by PLC, eluting three times with EtOAc, (2R,3R,4S)-2-*azido*-4-*diphenylphosphinoylhexane*-1,3-*diol* **24** (14.4 mg, 19%) as an oil, $[\alpha]_D^{25}$ +7.1 (*c* 1.44 in $CDCl_3$; >95% ee) (Found: M + H, 360.1486. $C_{18}H_{22}N_3O_3P$ requires *M* + H, 374.1511); R_F(EtOAc) 0.36; $\nu_{max}(CDCl_3)/cm^{-1}$ 3300 (OH), 2110 (N_3), 1440 (PPh) and 1150 (P=O); δ_H(400 MHz; $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 5.21 (1 H, s, CHO*H*), 4.14 (1 H, dt, *J* 1.6 and 10.5, C*H*OH), 4.05 (1 H, m, CH_AH_BOH), 3.95 (1 H, m, CH_AH_BOH), 3.65 (1 H, br t, CH_2OH), 3.42 (1 H, dt, *J* 10.0 and 5.3, CHN_3), 2.58 (1 H, dt, *J* 5.9 and 5.3, CHP), 1.94 (1 H, m, CH_AH_BMe), 1.65 (1 H, m, CH_AH_BMe) and 0.79 (3 H, t, *J* 7.5, Me); δ_C(62.9 MHz; $CDCl_3$) 134–128 (Ph_2PO), 68.7$^+$ ($^2J_{PC}$ 5.7, CHOH), 63.7$^+$ ($^3J_{PC}$ 12.3, CHN_3), 62.7$^-$ (CH_2OH), 39.4$^+$ ($^1J_{PC}$ 69.6, PCH), 15.1$^+$ ($^3J_{PC}$ 7.4, Me) and 14.6$^-$ (CH_2Me); *m*/*z* (+FAB) 360 (100%, M + H), 202 (38, Ph_2POH) and 201 (98, Ph_2PO). The peaks at δ 5.21 and 3.65 in the ^1H NMR spectrum disappear after a D_2O shake.

Also obtained was (2R,3S,4S)-3-*azido*-4-*diphenylphosphinoylhexane*-1,2-*diol* **23** (20.6 mg, 27%) as an oil, $[\alpha]_D^{25}$ −33.5 (*c* 2.06 in $CDCl_3$; >95% ee) (Found: M + H, 360.1441. $C_{18}H_{22}N_3O_3P$ requires *M* + H, 374.1511); R_F(EtOAc) 0.21; $\nu_{max}(CDCl_3)/cm^{-1}$ 3300 (OH), 2110 (N_3), 1440 (PPh) and 1150 (P=O); δ_H(400 MHz; $CDCl_3$) 7.9–7.4 (10 H, m, Ph_2PO), 6.31 (1 H, s, CHO*H*), 3.91 (1 H, ddd, *J* 13.9, 9.0 and 2.0, CHN_3), 3.75 (2 H, m, CH_AH_BOH and C*H*OH), 3.55 (1 H, m, CH_AH_BOH), 2.79 (1 H, dddd, *J* 13.5, 8.5, 4.2 and 2.2, CHP), 2.30 (1 H, br s, CH_2OH), 1.95–1.65 (2 H, m, CH_2Me) and 0.91 (3 H, t, *J* 7.4, Me); δ_C(100 MHz; $CDCl_3$) 134–128 (Ph_2PO), 69.7$^+$ (CHOH), 63.9$^-$ (CH_2OH), 62.2$^+$ (CHN_3), 43.2$^+$ ($^1J_{PC}$ 67.6, PCH), 18.0$^-$ (CH_2Me) and 13.9$^+$ ($^3J_{PC}$ 10.6, Me); *m*/*z* (+FAB) 360 (82%, M + H), 202 (32, Ph_2POH) and 201 (100, Ph_2PO).

Attack of trimethylsilyl azide on the expoxy alcohol *syn*-1g

In the same way, the epoxy alcohol[6] *syn*-**1g** (35.3 mg, 0.112 mmol) gave, after being heated under reflux for 2 h, and after purification by flash chromatography, (2R,3R,4R)-2-*azido*-4-*diphenylphosphinoylhexane*-1,3-*diol* **26** (15.7 mg, 39%) as an oil, $[\alpha]_D^{25}$ −13.1 (*c* 1.57 in $CDCl_3$; >95% ee) (Found: M + H, 360.1494. $C_{18}H_{22}N_3O_3P$ requires *M* + H, 374.1511); R_F(EtOAc) 0.31; $\nu_{max}(CDCl_3)/cm^{-1}$ 3300 (OH), 2110 (N_3), 1440 (PPh) and 1150 (P=O); δ_H(400 MHz; $CDCl_3$) 8.0–7.4 (10 H, m, Ph_2PO), 5.65 (1 H, d, *J* 7.6, CHO*H*), 4.0–3.75 (3 H, m, C*H*OH and CH_2OH), 3.20 (1 H, dt, *J* 1.05 and 4.9, CHN_3), 2.63 (1 H, dq, *J* 3.3 and 6.2, CHP), 2.50 (1 H, dd, *J* 7.6 and 4.5, CH_2OH), 1.87 (1 H, m, CH_AH_BMe), 1.47 (1 H, m, CH_AH_BMe) and 0.95 (3 H, t, *J* 7.4, Me); δ_C(62.9 MHz; $CDCl_3$) 134–128 (Ph_2PO), 73.1$^+$ ($^2J_{PC}$ 5.7, CHOH), 64.4$^+$ (CHN_3), 64.3$^-$ (CH_2OH), 38.6$^+$ ($^1J_{PC}$ 65.8, PCH), 20.4$^-$ (CH_2Me) and 12.6$^+$ ($^3J_{PC}$ 12.1, Me); *m*/*z* (+FAB) 360 (90%, M + H), 202 (45, Ph_2POH) and 201 (100, Ph_2PO). The peaks at δ 5.65 and 2.50 in the ^1H NMR spectrum disappear after a D_2O shake.

Also obtained was (2R,3S,4R)-3-*azido*-4-*diphenylphosphinoylhexane*-1,2-*diol* **25** (8.6 mg, 21%) as an oil, $[\alpha]_D^{25}$ −21.5 (*c* 0.86 in $CDCl_3$; >95% ee) (Found: M + H, 360.1495. $C_{18}H_{22}N_3O_3P$ requires *M* + H, 374.1511); R_F(EtOAc) 0.21; $\nu_{max}(CDCl_3)/cm^{-1}$ 3300 (OH), 2110 (N_3), 1440 (PPh) and 1150 (P=O); δ_H(400 MHz; $CDCl_3$) 7.9–7.4 (10 H, m, Ph_2PO), 4.7 (1 H, br s, CHO*H*), 4.04 (1 H, ddd, *J* 20.2, 9.8 and 1.8, CHN_3), 3.76 (1 H, dd, *J* 11.5 and 2.9, CH_AH_BOH), 3.65 (1 H, m, C*H*OH), 3.57 (1 H, m, *J* 11.5 and 4.7, CH_AH_BOH), 2.73 (1 H, t, *J* 10.0, CHP), 1.87 (1 H, m, CH_AH_BMe), 1.71 (1 H, m, CH_AH_BMe) and 0.93 (3 H, t, *J* 7.4, Me); δ_C(100 MHz; $CDCl_3$) 134–128 (Ph_2PO), 72.4$^+$ (CHOH), 63.8$^-$ (CH_2OH), 61.1$^+$ (CHN_3), 42.3$^+$ ($^1J_{PC}$ 67.6, PCH), 19.5$^-$ (CH_2Me) and 14.0$^+$ ($^3J_{PC}$ 11.4, Me); *m*/*z* (+FAB) 360 (60%, M + H), 202 (47, Ph_2POH) and 201 (100, Ph_2PO).

Attack of $Me_2AlNHBn$ on the epoxy alcohol *anti*-1e

Trimethylaluminium (2 mol dm^{-3} solution in toluene; 0.35 cm^3, 0.7 mmol, 2 equiv.) was added dropwise to a stirred solution of benzylamine (80 mm^3, 0.73 mmol, 2.1 equiv.) in dry dichloromethane (1 cm^3) at room temperature under nitrogen. Gas was evolved. After 45 min, this mixture was added to a stirred solution of the epoxy alcohol[6] *anti*-**1e** (115 mg, 0.348 mmol) in dry dichloromethane (2 cm^3) under nitrogen with continued stirring at room temperature for 3 days. Dilute aqueous sodium hydroxide (1 cm^3) and water (10 cm^3) were carefully added to the mixture which was then extracted with dichloromethane (× 3). The combined extracts were dried (Na_2SO_4) and evaporated under reduced pressure. Purification of the residue by flash chromatography, eluting with EtOAc and then EtOAc–10% MeOH, followed by HPLC, eluting with CH_2Cl_2–10% MeOH, gave the *amine* **27** (28.1 mg, 19%) (Found: M + H, 438.2161. $C_{26}H_{32}NO_3P$ requires *M* + H, 438.2198); R_F(EtOAc) 0.08; ν_{max}(film)/cm^{-1} 3600–3200 (OH and NH), 1440 (PPh) and 1170 (P=O); δ_H(250 MHz; $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 4.06 (1 H, d × fine m, *J* 9.3, C*H*OH), 3.93 (1 H, d, *J* 14.3, NCH_AH_BPh), 3.70 (3 H, m, NCH_AH_BPh and CH_2OH), 3.18 (1 H, d, *J* 8.2, CHP), 2.77 (1 H, d × fine m, *J* 9.0, CHN), 2.25 (1 H, m, $CHMe_2$), 1.11 (3 H, d, *J* 7.0, $CHMe_AMe_B$) and 0.74 (3 H, d, *J* 7.0, $CHMe_AMe_B$); δ_C(62.9 MHz; $CDCl_3$) 134–126 (Ph_2PO), 72.1$^+$ (CHOH), 65.0$^+$ (CHN), 64.8$^-$ (CH_2OH), 50.8$^-$ ($PhCH_2N$), 41.9$^+$ ($^1J_{PC}$ 67.0, PCH), 25.8$^+$ ($CHMe_2$), 24.0$^+$ ($CHMe_AMe_B$) and 22.8$^+$ ($CHMe_AMe_B$); *m*/*z* 376 (1%, M − $C_3H_4O_2$), 287 (58, $Ph_2POC_5H_{10}O$), 257 (28, $Ph_2POC_4H_8$), 202 (52, Ph_2POH) and 201 (100, Ph_2PO). Also obtained was starting material (29.4 mg, 25%).

In another experiment with the epoxy alcohol *anti*-**1e** (127 mg, 0.384 mmol), the reaction mixture was heated under reflux for 19 h. After work-up, purification of the residue by flash chromatography, eluting with CH_2Cl_2–10% MeOH, gave (S,Z)-4-*diphenylphosphinoyl*-5-*methylhex*-3-*ene*-1,2-*diol* **30** (69.3 mg, 55%) as an oil (Found: M − H_2O, 312.1303. $C_{19}H_{23}O_3P$ requires M, 312.1279); R_F(EtOAc) 0.26; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3100 (OH), 1440 (PPh) and 1150 (P=O); δ_H(250 MHz; $CDCl_3$) 7.9–7.4 (10 H, m, Ph_2PO), 6.62 (1 H, dd, *J* 39.0 and 7.4, C=CH), 4.77 (1 H, ddt, *J* 4.7, 2.3 and 6.6, C*H*OH), 3.65 (2 H, m,

CH_2OH), 2.15 (1 H, septet, *J* 7.0, $CHMe_2$), 0.91 (3 H, d, *J* 6.8, $CHMe_AMe_B$) and 0.83 (3 H, d, *J* 6.8, $CHMe_AMe_B$); δ_C(100 MHz; $CDCl_3$) 146.1$^+$ ($^2J_{PC}$ 5.7, PC=C), 141.8$^+$ ($^1J_{PC}$ 87.0, PC), 133–128 (Ph_2PO), 68.6$^+$ ($^3J_{PC}$ 7.2, CHOH), 65.1$^-$ (CH_2OH), 30.6$^+$ ($^2J_{PC}$ 15.3, $CHMe_2$) and 23.1$^+$ ($CHMe_2$); *m/z* 312 (6.5%, M − H_2O), 299 (100, M − CH_2OH), 202 (36, Ph_2POH) and 201 (51, Ph_2PO).

Irradiation of the signal at δ 4.80 in the ^1H NMR spectrum resulted in a NOE at δ 6.58 and at the *ortho* hydrogens of the Ph_2PO envelope (δ 7.7). Similarly, irradiation at δ 2.15 enhanced the signals at δ 6.58 and 7.7.

Attack of $Me_2AlNHBn$ on the epoxy alcohol *syn*-1e

In the same way, the epoxy alcohol[6] *syn*-**1e** (115 mg, 0.348 mmol) gave, after 20 h, work-up and purification by flash chromatography, eluting with CH_2Cl_2–6% MeOH, material (28.3 mg) which ^1H NMR showed to consist of a 1:1 mixture of starting material *syn*-**1e** and the amine **28**, $[\alpha]_D^{25}$ +22.9 (*c* 0.65 in $CHCl_3$; 65% ee) (Found: M − $C_3H_4O_2$, 376.1818. $C_{26}H_{32}NO_3P$ requires *M* − $C_3H_4O_2$, 376.1830); R_F(EtOAc) 0.08; ν_{max}(film)/cm^{-1} 3600–3200 (OH and NH), 1440 (PPh) and 1170 (P=O); δ_H(250 MHz; $CDCl_3$) 7.8–7.3 (10 H, m, Ph_2PO), 5.6 (1 H, br s, NH), 4.04 (1 H, dd, *J* 21.0 and 9.0, C*H*OH), 3.8–3.6 (3 H, m, $PhCH_2N$ and CH_AH_BOH), 3.58 (1 H, dd, *J* 11.4 and 4.6, CH_AH_BOH), 3.16 (1 H, d × fine m, *J* 9.7, CHP), 3.11 (1 H, d × fine m, *J* 8.3, CHN), 2.15 (1 H, m, $CHMe_2$), 1.10 (3 H, d, *J* 7.0, $CHMe_AMe_B$) and 1.07 (3 H, d, *J* 7.0, $CHMe_AMe_B$); δ_C(100 MHz; $CDCl_3$) 134–126 (Ph_2PO), 72.0$^+$ (CHOH), 60.8$^+$ (CHN), 60.4$^-$ (CH_2OH), 50.5$^-$ ($PhCH_2N$), 42.7$^+$ ($^1J_{PC}$ 67.1, PCH), 27.9$^+$ ($CHMe_2$), 22.9$^+$ ($^3J_{PC}$ 14.4, $CHMe_AMe_B$) and 18.9$^+$ ($CHMe_AMe_B$); *m/z* 376 (1%, M − $C_3H_4O_2$), 287 (58, $Ph_2POC_5H_{10}O$), 257 (28, $Ph_2POC_4H_8$), 202 (52, Ph_2POH) and 201 (100, Ph_2PO).

(*S*,*E*)-5-Methyl-2-(3-phenylpropylsulfanyl)hex-3-en-1-ol 31

Sodium hydride (60% suspension; 16 mg, 0.40 mmol, 3.7 equiv.) was added to a stirred solution of the sulfide **19** (37.3 mg, 0.094 mmol) in dry DMF (1.5 cm^3) under nitrogen. The mixture was heated to 60 °C for 30 min, cooled, quenched with saturated aqueous ammonium chloride (1 cm^3), and partitioned between ether (20 cm^3) and water (20 cm^3). The aqueous layer was separated, extracted with diethyl ether (× 2), and the combined extracts were washed with water, dried (Na_2SO_4) and evaporated under reduced pressure. Purification of the residue by PLC, eluting with hexane–EtOAc (4:1), gave the *sulfide* **31** (16.7 mg, 58%) as an oil, $[\alpha]_D^{25}$ −25.1 (*c* 1.19 in $CHCl_3$) (Found: M$^+$, 264.1566. $C_{16}H_{24}OS$ requires *M*, 264.1548); R_F[hexane–EtOAc (4:1)] 0.27; ν_{max}($CHCl_3$)/cm^{-1} 3600–3300 (OH) and 1600 (Ph); δ_H(250 MHz; $CDCl_3$) 7.3–7.1 (5 H, m, Ph), 5.53 (1 H, dd, *J* 15.5 and 6.6, C*H*=CHS), 5.24 (1 H, ddd, *J* 15.4, 8.7 and 1.0, CH=C*H*S), 3.63 (1 H, dd, *J* 11.1 and 6.5, CH_AH_BOH), 3.57 (1 H, dd, *J* 11.1 and 6.9, CH_AH_BOH), 3.32 (1 H, br q, *J* 7, C*H*SCH_2), 2.70 (2 H, ABXY m, CH_2Ph), 2.47 (2 H, br m, CH_2S), 2.28 (1 H, octet, *J* 6.7, $CHMe_2$), 1.89 (2 H, quintet, *J* 7.3, $CH_2CH_2CH_2$), 1.85 (1 H, br s, OH) and 0.96 (6 H, d, *J* 6.7, $CHMe_2$); δ_C(100 MHz; $CDCl_3$) 142–124 (Ph and C=C), 64.2$^-$ (CH_2OH), 50.7$^+$ ($CHSCH_2$), 34.8$^-$, 31.3$^-$, 29.2$^-$ [$(CH_2)_3$], 31.0$^+$ ($CHMe_2$), 22.42$^+$ and 22.40$^+$ ($CHMe_2$); *m/z* 264 (2%, M$^+$), 234 (100, M − CH_2O), 112 (77, M − $Ph(CH_2)_3S$) and 91 (82, $PhCH_2$).

Addition of D_2O to the ^1H NMR sample resolves δ 3.32 (1 H, br q, C*H*SCH_2) to 3.75 (1 H, q, *J* 6.7) and 2.47 (2 H, br m, CH_2S) to 2.47 (2 H, t, *J* 7.4).

(*S*,*E*)-5-Methyl-2-(3-phenylpropylsulfanyl)hex-3-en-1-ol 32

In the same way, the diol **21** (64.8 mg, 0.187 mmol), with sodium hydride (60% suspension; 25 mg, 0.625 mmol, 3.3 equiv.) gave, after 10 min at 60 °C, and after purification by PLC, eluting with hexane–EtOAc (4:1), the *alcohol* **32** (20.7 mg, 86%) as an oil, $[\alpha]_D^{25}$ +14.3 (*c* 1.02 in $CHCl_3$; 65% ee) [lit.,[14] + 28.4 (*c* 1.0 in $CHCl_3$; 92% ee)]; R_F [hexane–EtOAc (4:1)] 0.28; ν_{max}($CHCl_3$)/cm^{-1} 3600–3400 (OH); δ_H(250 MHz; $CDCl_3$) 5.51 (1 H, ddd, *J* 15.5, 6.6 and 0.7, Me_2CHCH=C*H*), 5.18 (1 H, ddd, *J* 15.5, 7.8 and 1.2, Me_2CHC*H*=CH), 3.46 (1 H, dd, *J* 10.4 and 5.6, CH_AH_BOH), 3.32 (1 H, dd, *J* 10.4 and 7.9, CH_AH_BOH), 2.26 (2 H, m, C*H*Me_2 and $HOCH_2CHMe$), 0.97 (6 H, d, *J* 6.7, $CHMe_2$) and 0.96 (3 H, d, *J* 6.8, $HOCH_2CHMe$); δ_C(100 MHz; $CDCl_3$) 139.7$^+$, 129.0$^+$ (CH=CH), 67.3$^-$ (CH_2OH), 39.6$^+$ ($HOCH_2CH$), 31.0$^+$ (Me_2CH), 22.64$^+$, 22.56$^+$ and 16.6$^+$ (Me × 3).

(*S*,*Z*)-5-Methyl-2-(3-phenylpropylsulfanyl)hex-3-en-1-ol 33

In the same way, the sulfide **18** (35.4 mg, 0.0734 mmol), with sodium hydride (60% suspension; 14.25 mg, 0.356 mmol, 4.8 equiv.) gave, after 75 min at 80 °C, and after purification by PLC, eluting with hexane–EtOAc (7:3), the *sulfide* **33** (3.2 mg, 16%) as an oil, $[\alpha]_D^{25}$ +33.1 (*c* 0.32 in $CDCl_3$; 85% ee) (Found: M$^+$, 264.1557. $C_{16}H_{24}OS$ requires *M*, 264.1548); R_F[hexane–EtOAc (4:1)] 0.27; ν_{max}($CHCl_3$)/cm^{-1} 3700 (OH) and 1600 (Ph); δ_H(250 MHz; $CDCl_3$) 7.3–7.1 (5 H, m, Ph), 5.42 (1 H, t, *J* 10.4, C*H*=CHCHS), 5.17 (1 H, t, *J* 10.4, CH=C*H*CHS), 3.75 (1 H, br s, C*H*SCH_2), 3.56 (2 H, d, *J* 6.5, CH_2OH), 2.71 (2 H, t, *J* 7.3, CH_2Ph), 2.6 (2 H, br s, CH_2S), 2.55 (1 H, m, C*H*Me_2), 1.90 (2 H, quintet, *J* 7.0, $CH_2CH_2CH_2$) and 0.96 (6 H, d, *J* 6.6, $CHMe_2$); *m/z* 264 (0.3%, M$^+$), 233 (34, M − CH_2OH), 112 [100, M − $Ph(CH_2)_3S$] and 91 (98, $PhCH_2$).

Addition of D_2O to the ^1H NMR sample resolves δ 3.75 (1 H, br s, C*H*SCH_2) to 3.75 (1 H, dt, *J* 10.1 and 7.0) and 2.6 (2 H, br s, CH_2S) to 2.51 (2 H, t, *J* 7.0).

(3*RS*,4*SR*,5*RS*)-5-Diphenylphosphinoyl-3,4-epoxydecan-2-one 34

Jones reagent (2.66 mol dm^{-3} in CrO_3; 0.65 cm^3) was added in one portion to a stirred solution of the epoxy alcohol *anti*,*syn*-**1b** (100 mg, 0.28 mmol) in acetone (5 cm^3). After being stirred for 30 min at 0 °C, the mixture was carefully poured into saturated aqueous $NaHCO_3$ (50 cm^3) and extracted with ether (2 × 50 cm^3). The combined extracts were dried ($MgSO_4$) and evaporated under reduced pressure to give the *epoxy ketone* **32** (62 mg, 62%) as a solid, mp 114–114.5 °C (from EtOAc–hexane) (Found: C, 71.25; H, 7.2; P, 8.15%; M$^+$, 370.1686. $C_{22}H_{27}O_3P$ requires C, 71.35; H, 7.30; P, 8.40%; *M*, 370.698); ν_{max}($CHCl_3$)/cm^{-1} 1708 (C=O), 1441 (P–Ph) and 1181 (P=O); δ_H(250 MHz; $CDCl_3$) 0.81 (3 H, t, *J* 7, CH_3CH_2), 1.0–2.4 [9 H, m, $(CH_2)_4$ and PCH], 1.80 (3 H, s, MeC=O), 2.92 (1 H, d, *J* 2, CHC=O), 3.31 (1 H, dt, *J* 9 and 2, C*H*CHP) and 7.3–8.0 (10 H, m, Ph_2PO); *m/z* 370 (2%), 327 (20, M − MeCO), 257 (57, $Ph_2POCHCHCHO$), 219 (34, $Ph_2PO_2H_2$), 202 (84, Ph_2POH) and 201 (100, Ph_2PO).

(3*RS*,4*SR*,5*SR*)-5-Diphenylphosphinoyl-3,4-epoxydecan-2-one 35

In the same way, the epoxy alcohol *syn*,*anti*-**1b** (600 mg, 1.688 mmol) gave the *epoxy ketone* **35** (468 mg, 74%) as a solid, mp 120–121 °C (from EtOAc–hexane) (Found: C, 71.0; H, 7.13; P, 8.57. $C_{22}H_{27}O_3P$ requires C, 71.35; H, 7.30; P, 8.40%) (Found: M − MeC=O, 327.1506. $C_{20}H_{24}O_2P$ requires M^+, 327.1514); ν_{max}($CHCl_3$)/cm^{-1} 1708 (C=O), 1441 (P–Ph) and 1181 (P=O); δ_H(250 MHz; $CDCl_3$) 0.83 (3 H, t, *J* 7, CH_3CH_2), 1.0–1.7 [8 H, m, $(CH_2)_4$], 1.98 (3 H, s, MeC=O), 2.2–2.4 (1 H, m, PCH), 3.25–3.35 (2 H, m, CHCHC=O) and 7.4–7.9 (10 H, m, Ph_2PO); *m/z* 327 (23%, M − MeCO), 257 (53, $Ph_2POCHCHCHO$), 219 (41, $Ph_2PO_2H_2$), 202 (70, Ph_2POH) and 201 (100, Ph_2PO).

(3*RS*,4*SR*,5*SR*)-5-Diphenylphosphinoyl-3,4-epoxy-4-methyldecan-2-one 36

A solution of the epoxy alcohol *anti,syn*-**1f** (116 mg, 0.3 mmol) in dichloromethane (1.5 cm^3) was added to a stirred suspension of pyridinium chlorochromate (162 mg, 0.75 mmol) in dichloromethane (3.5 cm^3). Stirring was continued at room temperature for 2 h after which the mixture was diluted with diethyl ether (5 cm^3) and stirred for 10 min. The supernatant liquid was removed and the residual tar was extracted with ether (3 × 10 cm^3). The combined extracts were washed with 2 mol dm^{-3} aq. NaOH (2 × 20 cm^3) and water (20 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a mixture of product and unchanged starting material. Purification of the mixture by flash chromatography (SiO_2, EtOAc) gave the *epoxy ketone* **36** [41 mg, 36% (54% based on recovered starting material)] as a solid, mp 158–161 °C, R_F(EtOAc) 0.36 (Found: M, 384.1858. $C_{23}H_{29}O_3P$ requires M^+, 384.1854); $\nu_{max}(CHCl_3)/cm^{-1}$ 1725 (C=O), 1440 (P–Ph) and 1180 (P=O); δ_H(250 MHz; $CDCl_3$) 0.832 (3 H, t, *J* 7, CH_3CH_2), 1.1–2.1 [8 H, m, $(CH_2)_4$], 1.36 (3 H, s, MeC), 1.67 (3 H, s, MeC=O), 2.31 (1 H, dt, *J* 2 and 10, PCH), 3.36 (1 H, s, CHC=O) and 7.4–8.0 (10 H, m, Ph_2PO); *m/z* 384 (10%), 355 (15), 341 (16, M − MeCO), 219 (20, $Ph_2PO_2H_2$) and 202 (100, Ph_2POH).

(3*RS*,4*SR*,5*SR*)-5-Diphenylphosphinoyl-3,4-epoxy-4-methyldecan-2-one 37

By the method given for **35**, the epoxy alcohol *syn,syn*-**1f** (2.05 g, 5.3 mmol) gave, after purification by flash chromatography (eluting with EtOAc) the *epoxy ketone* **37** (1.57 g, 77%) as a solid, mp 131.5–132.5 °C (from hexane–EtOAc) (Found: M, 384.1846. $C_{23}H_{29}O_3P$ requires M^+, 384.1854); $\nu_{max}(CHCl_3)/cm^{-1}$ 1715 (C=O), 1438 (P–Ph) and 1170 (P=O); δ_H(250 MHz; $CDCl_3$) 0.82 (3 H, t, *J* 7, CH_3CH_2), 1.1–2.0 [8 H, m, $(CH_2)_4$], 1.26 (3 H, s, MeC), 2.13 (3 H, s, MeC=O), 2.37 (1 H, m, PCH), 3.78 (1 H, s, CHC=O) and 7.4–8.0 (10 H, m, Ph_2PO); δ_C(100 MHz; $CDCl_3$) 13.9 (q, CH_3CH_2), 17.8 (q, CH_3C), 22.3 (t, $MeCH_2$), 25.5 (t, $MeCH_2CH_2$), 28.2 (q, CH_3C=O), 28.8 (dt, J_{PC} 11.4, $PCHCH_2CH_2$), 31.6 (t, $PCHCH_2$), 46.4 (dd, J_{PC} 67, PCH), 61.7 (s, MeCCHP), 63.3 (dd, J_{PC} 9.2, CHC=O), 128.5–133.7 (10 C, m, Ph_2PO) and 203.3 (s, C=O); *m/z* 384 (11%), 355 (15), 341 (19, M − MeCO), 219 (27, $Ph_2PO_2H_2$), 202 (100, Ph_2POH) and 201 (78, Ph_2PO).

Addition of $Ph(CH_2)_3SH$ to the epoxy ketone 34

A solution of the crude epoxy ketone **34** (222 mg, 0.6 mmol) and 3-phenylpropanethiol (0.2 cm^3, 1.2 mmol) in a mixture of triethylamine (0.5 cm^3) and methanol (0.5 cm^3) was stirred at room temperature under nitrogen for 16 h. The reaction mixture was then applied directly to three PLC plates (SiO_2, EtOAc–50% hexane) which gave the adduct (234 mg, 75% overall yield from **34**) as an oil. ^1H NMR spectroscopy showed this to be a mixture of the (3*RS*,4*RS*,5*RS*)- and (3*RS*,4*SR*,5*SR*)-diastereoisomers of 5-*diphenylphosphinoyl*-2-*oxo*-3-(3-*phenylpropylsulfanyl*)*decan*-4-*ol* **38**. The diastereoisomeric ratio was *ca.* 5:1 [Found: $M^+ - Ph(CH_2)_3SCHC(OH)Me$, 314.1427. $C_{19}H_{23}O_2P$ requires 314.1435]; R_F(EtOAc–50% hexane) 0.32; $\nu_{max}(CHCl_3)/cm^{-1}$ 3350 (OH), 1603 (C=O), 1441 (P–Ph) and 1180 (P=O); δ_H(250 MHz; $CDCl_3$) 0.74 (3 H, t, *J* 6, CH_3CH_2), 0.8–3.0 (15 H, m), 2.23 (3 H, s, MeCO), 3.37^{major} and 3.57^{minor} (1 H, 2 × d, *J* 10^{major} and 9^{minor}, SCH), 4.29 (1 H, t, *J* 10, CHOH), 7.0–7.4 (5 H, m, $PhCH_2$) and 7.4–8.0 (10 H, m, Ph_2PO); *m/z* 314 [4%, M − $Ph(CH_2)_3SCHC(OH)Me$], 286 [15, $Ph_2POHCH(CH_2)_4Me$], 244 (25), 229 (40, $Ph_2POC_2H_4$), 208, [55, $Ph(CH_2)_3SCHC(OH)Me$], 202 (50, Ph_2POH), 201 (50, Ph_2PO) and 91 (100, C_7H_7).

Addition of $Ph(CH_2)_3SH$ to the epoxy ketone 35

In a similar way, the epoxy ketone **35** gave the adduct (275 mg, 88%) as an oil. The ^1H NMR spectrum of the product showed it to be a mixture of the (3*RS*,4*RS*,5*SR*)- and (3*RS*,4*SR*,5*RS*)-diastereoisomers of 5-diphenylphosphinoyl-2-oxo-3-(3-phenylpropylsulfanyl)decan-4-ol **40**. The diastereoisomeric ratio was determined to be 4:1 by comparison of the signals at δ 3.12 and 3.84 in the ^1H NMR spectrum; R_F(EtOAc–50% hexane) 0.32; $\nu_{max}(CHCl_3)/cm^{-1}$ 3300 (OH), 1704 (C=O), 1441 (P–Ph) and 1170 (P=O); δ_H(250 MHz; $CDCl_3$ + D_2O) 0.84 (3 H, br t, *J* 7, CH_3CH_2), 1.0–3.1 (15 H, m), 2.13 (3 H, s, MeCO), 3.12^{major} and 3.84^{minor} (1 H, 2 × d, *J* 10^{major} and 8^{minor}, CHS), 4.1–4.3 (1 H, m, CHOH), 7.0–7.3 (5 H, m, CH_2Ph) and 7.3–8.0 (10 H, m, Ph_2PO); *m/z* 327 (8%), 314 [2, M − $Ph(CH_2)_3SCHC(OH)Me$], 286 [7, $Ph_2P(OH)CH(CH_2)_4Me$], 208 [92, $Ph(CH_2)_3SCHCH(OH)Me$], 202 (26, Ph_2POH) and 201 (26, Ph_2PO).

Attempted addition of $Ph(CH_2)_3SH$ to the epoxy ketone 36

Butyllithium (1.5 mol dm^{-3} solution in hexane; 0.15 cm^3, 0.22 mmol) was added in one portion to a stirred solution of $Ph(CH_2)_3SH$ (0.15 cm^3, 1 mmol) in THF (2 cm^3) at 0 °C under nitrogen and stirring was continued for 5 min. The epoxy ketone **36** (100 mg, 0.26 mmol) was added in one portion to the solution which was then warmed to room temperature. Stirring was continued for 40 min after which the mixture was diluted with diethyl ether (50 cm^3), washed with saturated aqueous $CuSO_4$ (2 × 25 cm^3) and water (25 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give an oil. PLC (SiO_2, EtOAc–60% hexane) of this gave 1-(3-phenylpropylsulfanyl)propan-2-one **44** (22 mg, 38%) as an oil, R_F(EtOAc–40% hexane) 0.67 (Found: M^+, 208.0921. $C_{12}H_{16}OS$ requires *M*, 208.0921); $\nu_{max}(CHCl_3)/cm^{-1}$ 1705 (C=O); δ_H(250 MHz; $CDCl_3$) 1.87 (2 H, qn, *J* 7, $CH_2CH_2CH_2$), 2.27 (3 H, s, MeCO), 2.50 and 2.80 (4 H, 2 × t, *J* 7, CH_2), 3.20 (2 H, s, SCH_2) and 7.1–7.5 (5 H, m, Ph); *m/z* 208 (100%), 150 [38, $Ph(CH_2)_3SH$], 149 [33, $Ph(CH_2)_3S$], 118 (85, $PhCH_2CHCH_2$), 117 (80, M − C_7H_7) and 91 (85, C_7H_7).

Also obtained was 3-diphenylphosphinoyloctan-2-one **43** (48 mg, 56%) as an oil, R_F(EtOAc–40% hexane) 0.26; $\nu_{max}(CHCl_3)/cm^{-1}$ 1705 (C=O), 1443 (P–Ph) and 1205 (P=O); δ_H(250 MHz; $CDCl_3$) 0.83 (3 H, t, *J* 6, CH_3CH_2), 1.0–2.5 [8 H, m, $(CH_2)_4$], 2.24 (3 H, s, MeCO), 3.61 (1 H, dt, *J* 12 and 3, PCH) and 7.4–8.1 (10 H, m, Ph_2PO); *m/z* 328 (8%, M), 285 (6, M − MeCO), 258 (80, M − C_5H_9) and 202 (100, Ph_2POH).

5-Diphenylphosphinoyl-3-(3-phenylpropylsulfanyl)decane-2,4-diol 39

Sodium borohydride (100 mg, excess), was added in one portion to a stirred solution of the ketone **38** (200 mg, 0.54 mmol) in methanol (8 cm^3) and stirring was continued at 0 °C for 30 min. Saturated aqueous NH_4Cl (10 cm^3) was then added dropwise to the mixture followed by water (80 cm^3). The resulting suspension was extracted with dichloromethane (2 × 40 cm^3) and the combined extracts were dried ($MgSO_4$) and evaporated under reduced pressure to give an oil. Purification of this by PLC (SiO_2, EtOAc–50% hexane) gave a major diastereoisomer **39** (120 mg, 60%) as an oil, R_F(EtOAc–50% hexane) 0.31 (Found: $M^+ - H_2O$, 506.2385. $C_{31}H_{39}O_2PS$ requires 506.2408); $\nu_{max}(CHCl_3)/cm^{-1}$ 3400 (OH), 1440 (P–Ph) and 1166 (P=O); δ_H(250 MHz; $CDCl_3$) 0.67 (3 H, t, *J* 7, CH_3CH_2) 0.9–1.2 and 1.6–2.0 [8 H, m, $(CH_2)_4$], 1.27 (3 H, d, *J* 6, CH_3CH), 1.92 (2 H, qn, *J* 7.5, CH_2CH_2S), 2.56 (2 H, ABX_2 m, CH_2S), 2.72 (2 H, t, *J* 7.5, CH_2Ph), 2.89 (1 H, dd, *J* 2.5 and 10, SCH), 2.95 (1 H, m, PCH), 4.0–4.2 (1 H, m, MeCHOH), 4.16 (1 H, t, *J* 10, CHOH) and 7.0–8.0 (15 H, m, Ph_2PO and Ph); *m/z* 506 (1%, M − H_2O), 488 (4, M − H_2O − H_2O), 462 (3, M − MeCHO − H_2O), 353 [22, M − $Ph(CH_2)_3S$ − H_2O], 315 [75, M − $Ph(CH_2)_3SCHCH(OH)Me$], 202 (56, Ph_2POH) and 201 (100, Ph_2PO).

Also obtained was a minor *diastereoisomer* of **39** (30 mg, 15%) as an oil, R_F(EtOAc–50% hexane) 0.23 (Found: $M^+ - 2H_2O$, 488.2318. $C_{31}H_{37}OPS$ requires $M^+ - 2H_2O$, 488.2302); $\nu_{max}(CHCl_3)/cm^{-1}$ 3350 (OH), 1443 (P–Ph) and 1166 (P=O); δ_H(250 MHz; $CDCl_3$ + D_2O) 0.70 (3 H, t, *J* 7, CH_3CH_2) 0.9–2.0 [8 H, m, $(CH_2)_4$], 1.24 (3 H, d, *J* 6, CH_3CH), 1.90 (2 H, qn, *J* 7.5, CH_2CH_2S), 2.4–2.7 (6 H, m, CH_2SCH, CH_2Ph and PCH), 4.27 (1 H, dq, *J* 2.6 and 6.2, MeC*H*), 4.40 (1 H, ddd, *J* 3.6, 6.5 and 11.7, PCHC*H*), 7.0–7.3 (5 H, m, *Ph*CH_2) and 7.3–8.0 (10 H, m, Ph_2PO). Irradiation of the signal at δ 2.19 simplified the signals at δ 4.27 and 4.40 to (1 H, q, *J* 6.2) and (1 H, dd, *J* 11.7 and 3.6), respectively. Irradiation of the signal at δ 1.24 simplified the signal at δ 4.27 to (1 H, d, *J* 2.6). Irradiation of the signal at δ 2.06 simplified the signal at δ 4.40 to (1 H, dd, *J* 11.7 and 6.5); *m/z* 488 (4%, M – H_2O – H_2O), 355 [31, M – $Ph(CH_2)_3S$ – H_2O], 315 [44, M – $Ph(CH_2)_3SCHCH(OH)Me$], 202 (90, Ph_2POH) and 201 (100, Ph_2PO).

5-Diphenylphosphinoyl-3-(3-phenylpropylsulfanyl)decane-2,4-diol 41

Sodium borohydride (150 mg, excess) was added in one portion to a stirred solution of the ketone **40** (270 mg) in methanol (8 cm^3) at 0 °C and stirring was continued for 30 min before careful quenching of the reaction mixture with saturated aqueous NH_4Cl (10 cm^3). After dilution with water (80 cm^3) the mixture was extracted with dichloromethane (2 × 40 cm^3) and the combined extracts were dried (Na_2SO_4) and evaporated to give an oil. Purification of this crude product by PLC (SiO_2, EtOAc–33% hexane) gave one diastereoisomer of the *diol* **41** (175 mg, 65%) as an oil, R_F(EtOAc–33% hexane) 0.34 (Found: $M^+ - H_2O$, 506.2410. $C_{31}H_{39}O_2PS$ requires *M*, 506.2408); $\nu_{max}(CHCl_3)/cm^{-1}$ 3330 (OH), 1590 and 1605 (C=C), 1439 (P–Ph) and 1152 (P=O); δ_H(250 MHz; $CDCl_3$ + D_2O) 0.83 (3 H, t, *J* 7, CH_3CH_2), 1.0–2.6 [6 H, m, $Me(CH_2)_3$], 1.28 (3 H, d, *J* 6, CH_3CH), 1.73 (2 H, quintet, *J* 7.5, CH_2CH_2S), 1.9–2.4 (4 H, m, $PCHCH_2$ and SCH_2), 2.60 (3 H, t, *J* 7.5, $PhCH_2$), 2.65 (1 H, dd, *J* 10 and 2, SCH), 3.13 (1 H, tt, J_{HP} 9, J_{HH} 9 2 and 2, PCH), 4.10 (1 H, ddd, J_{HP} 23, J_{HH} 10 and 2, PCHC*H*), 4.14 (1 H, dq, *J* 2 and 6, MeC*H*), 7.0–7.3 (5 H, m, *Ph*CH_2) and 7.3–8.0 (10 H, m, Ph_2PO). Irradiation at δ 3.13 simplified the signal at δ 4.14 to (1 H, q, *J* 6) and the signal at δ 4.10 to (1 H, dd, *J* 10 and 23). Irradiation at δ 1.28 simplified the signal at δ 4.14 to (1 H, d, *J* 2); *m/z* 506 (0.5%, M – H_2O), 488 (1.5, M – H_2O – H_2O), 315 [35, M – $Ph(CH_2)_3SCHCH(OH)Me$], 201 (57, Ph_2PO) and 181 (100).

(2*RS*,3*SR*,Z)-3-(3-Phenylpropylsulfanyl)dec-4-en-2-ol 46

Sodium hydride (80% dispersion in mineral oil; 30 mg, 1 mmol) was added in one portion to a stirred solution of the β-hydroxy phosphine oxide **17** (100 mg, 0.19 mmol) in DMF (4 cm^3) at room temperature under nitrogen. The resulting solution was heated at 75 °C for 2 h to give a black solution with a precipitate which was then allowed to cool. The reaction was quenched by the careful dropwise addition of saturated aqueous NH_4Cl (2 cm^3) to the mixture followed by water (40 cm^3). The resulting solution was extracted with ether (50 cm^3). The extract was washed with water (3 × 40 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give an oil. This crude product was purified by PLC (SiO_2, EtOAc–90% hexane) to give the *allylic sulfide* **46** (10 mg, 17%) as a colourless oil, R_F(EtOAc–80% hexane) 0.41 (Found: M^+, 306.2030. $C_{19}H_{30}OS$ requires *M*, 306.2017); $\nu_{max}(CHCl_3)/cm^{-1}$ 3400 (OH) and 1660 (C=C); δ_H(250 MHz; $CDCl_3$) 0.88 (3 H, t, *J* 7, $CHCH_2$), 1.21 (3 H, d, *J* 6.2, CH_3CH), 1.1–1.8 [6 H, m, $Me(CH_2)_3$], 1.90 (2 H, qn, *J* 7.5, CH_2CH_2S), 2.04 (2 H, br q, *J* 7, CH_2CH=CH), 2.4–2.6 (2 H, br s, CH_2S), 2.71 (2 H, t, *J* 7.5, CH_2Ph), 3.64 (1 H, dd, *J* 4.7 and 11, SCH), 3.81 (1 H, dq, *J* 4.7 and 6.2, C*H*OH), 5.34 (1 H, tt, *J* 11 and 1.5, CH=C*H*CH), 5.65 (1 H, dt, *J* 11 and 7, C*H*=CHCH) and 7.1–7.3 (5 H, m, Ph). Irradiation of the signal at δ 3.64 simplified the signal at δ 3.81 to (1 H, q, *J* 6.2) and the signal at δ 5.34 to (1 H, br d, *J* 11); *m/z* 306 (2%), 262 (22, M – MeCHO), 261 (38, M – MeCHOH), 117 (50), 118 (48) and 92 (100, C_7H_7).

(2*RS*,3*RS*,Z)-3-(3-Phenylpropylsulfanyl)dec-4-en-2-ol 47

Sodium hydride (80% dispersion in mineral oil; 30 mg, 1.0 mmol) was added in one portion to a stirred solution of the diol **39** (100 mg, 0.27 mmol) in DMF (4 cm^3) at room temperature under nitrogen after which the mixture was heated at 75 °C for 2 h. After cooling, the reaction mixture was carefully quenched by the dropwise addition to it of saturated aqueous NH_4Cl (5 cm^3). It was then diluted with diethyl ether, washed with water (4 × 40 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give an oil. Purification of this by PLC (SiO_2, EtOAc–85% hexane) gave the *allylic sulfide* **47** (20 mg, 30%) as an oil, R_F(EtOAc–80% hexane) 0.41 (Found: M^+, 306.2007. $C_{19}H_{30}OS$ requires *M*, 306.2017); $\nu_{max}(CHCl_3)/cm^{-1}$ 3450 (OH) and 1600 (C=C); δ_H(250 MHz; $CDCl_3$) 0.85 (3 H, t, *J* 7, CH_3CH_2), 1.15 (3 H, d, *J* 6.5, CH_3CH), 1.15–1.4 [6 H, m, $Me(CH_2)_3$], 1.85 (2 H, qn, *J* 7.5, CH_2CH_2S), 1.9–2.05 (2 H, br m, CH_2CH=C), 2.46 and 2.66 (4 H, 2 × t, *J* 7.5, $CH_2CH_2CH_2S$), 3.42 (1 H, dd, *J* 10.5 and 8.5, CHS), 3.59 (1 H, dq, *J* 8.5 and 6.5, C*H*OH) 5.21 (1 H, br t, *J* 10, CHC*H*=CH), 5.49 (1 H, dt, *J* 10.5 and 7, CHCH=C*H*) and 7.1–7.35 (5 H, m, Ph); *m/z* 306 (7%), 262 (60, M – MeCO), 261 (100, M – MeCHOH) and 152 [60, $Ph(CH_2)_3SH$].

Also obtained was (Z)-1-(3-phenylpropylsulfanyl)oct-2-ene **48** (20 mg, 40%) as an oil, R_F(EtOAc–80% hexane) 0.70 (Found: M^+, 262.1772. $C_{17}H_{26}S$ requires *M*, 262.1755); $\nu_{max}(CHCl_3)/cm^{-1}$ 1600 (C=C); δ_H(250 MHz; $CDCl_3$) 0.86 (3 H, t, *J* 7, CH_3CH_2), 1.0–1.4 [6 H, m, $(CH_2)_3$], 1.91 (2 H, qn, *J* 7.5, CH_2CH_2S), 2.04 (2 H, br q, *J* 7, CH_2CH=C), 2.50 and 2.72 (4 H, 2 × t, *J* 7.5, $CH_2CH_2CH_2S$), 3.17 (2 H, d, *J* 8, CH_2S), 5.44 (1 H, dt, *J* 10.5 and 8, SCH_2CH=CH), 5.54 (1 H, dt, *J* 10.5 and 6, SCH_2CH=C*H*) and 7.1–7.4 (5 H, m, Ph). Irradiation of the signal at δ 3.17 simplified the signal at δ 5.44 to (1 H, d, *J* 10.5) and irradiation of the signal at δ 1.91 simplified the signals at δ 2.50 and 2.72 to 2 × (2 H, s); *m/z* 262 (5%), 168 (9), 152 [16, $Ph(CH_2)_3SH$], 126 (100), 118 (30, $PhCH_2CHCH_2$), 117 (27) and 91 (45, C_7H_7).

(2*RS*,3*RS*,E)-3-(3-Phenylpropylsulfanyl)dec-4-en-2-ol 49

Sodium hydride (80% dispersion in mineral oil; 30 mg, 1.0 mmol) was added in one portion to a stirred solution of the diol **39** (130 mg, 0.35 mmol) in DMF (4 cm^3) at room temperature under nitrogen. The resulting solution was heated at 60 °C for 15 min before it was cooled and quenched by the dropwise addition of saturated aqueous NH_4Cl (5 cm^3). The mixture was then diluted with diethyl ether (100 cm^3), washed with water (4 × 50 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give an oil. Purification of this by PLC (SiO_2, EtOAc–80% hexane) gave the *allylic sulfide* **49** (58 mg, 76%) as a colourless oil, R_F(EtOAc–80% hexane) 0.41 (Found: M^+, 306.2020. $C_{19}H_{30}OS$ requires *M*, 306.2017); $\nu_{max}(CHCl_3)/cm^{-1}$ 3400 (OH) and 1606 (C=C); δ_H(250 MHz; $CDCl_3$) 0.86 (3 H, t, *J* 7, *Me*CH_2), 1.14 (3 H, d, *J* 6, CH_3CH), 1.15–1.35 [6 H, m, $Me(CH_2)_3$], 1.89 (2 H, qn, *J* 7.5, CH_2CH_2S), 2.00 (2 H, br q, *J* 7, CH_2CH=C), 2.0–2.5 (2 H, br s, CH_2S), 2.6–2.8 (2 H, ABX_2 m, CH_2Ph), 2.8–3.3 (1 H, br s, CHS), 3.69 (1 H, dq, *J* 8 and 6, C*H*OH), 5.30 (1 H, dd, *J* 15 and 9, C*H*=CHCH$_2$), 5.48 (1 H, dt, *J* 15 and 7, CH=C*H*CH$_2$) and 7.2–7.4 (5 H, m, Ph). Addition of D_2O caused the two broad singlets to become δ 2.45 (2 H, t, *J* 7.5, CH_2S) and 3.04 (1 H, dd, *J* 9 and 8, CHS); *m/z* 306 (2%), 262 (27, M – MeCHO), 261 (33, M – MeCHOH), 118 (48), 117 (48) and 91 (100, C_7H_7).

(2*RS*,3*SR*)-4-Methyl-3-(3-phenylpropylsulfanyl)dec-4-en-2-ol 50

Sodium hydride (50% dispersion in mineral oil; 10 mg, 0.21

mmol) was added in one portion to a stirred solution of the alcohol **16** (100 mg, 0.185 mmol) in DMF (3 cm^3) and the resulting solution was heated at 50 °C for 25 min. Further sodium hydride (10 mg) was then added to the mixture and stirring continued for 15 min at 50 °C. After cooling, the mixture was carefully quenched with sat. aq. NH_4Cl (5 cm^3), diluted with water (30 cm^3) and extracted with ether (70 cm^3). The extract was washed with water (3 × 30 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give an oil. TLC of this crude produce showed a complex mixture with major components at R_F(EtOAc–75% hexane) 0.1, 0.43, 0.54 and 0.64. These components were separated by PLC (EtOAc–75% hexane) to give hexyldiphenylphosphine oxide (35 mg, 66%) as an oil R_F 0.1, and a minor product which was tentatively assigned as the *allylic sulfide* **50** (6 mg, 10%), R_F 0.43; δ_H(250 MHz; $CDCl_3$) 0.90 (3 H, t, *J* 7, CH_3CH_2), 1.28 (3 H, d, *J* 7, CH_3CH), 1.65 (3 H, br s, MeC=C), 1.1–2.2 [10 H, m, $(CH_2)_4$ and SCH_2], 2.35 and 2.65 (4 H, m, CHOH), 5.26 (1 H, br t, *J* 6, C=CH) and 6.95–7.2 (5 H, br s, Ph).

(2*S*,3*S*,4*S*)-4-Diphenylphosphinoyl-2,3-epoxy-5-methylhexanoic acid 52

Water (12 cm^3), sodium periodate (1.228 g, 5.74 mmol, 4.2 equiv.) and ruthenium(III) chloride (5 mg, 1.5 mol%) were added to a stirred solution of the epoxy alcohol[6] *syn*-**1e** (453.6 mg, 1.37 mmol) in a mixture of carbon tetrachloride (8 cm^3) and acetonitrile (8 cm^3). The brown, two-phase mixture was stirred vigorously for 4 h after which it was diluted with dichloromethane (100 cm^3) and water (50 cm^3) and then basified with dilute aqueous sodium hydroxide (2 mol dm^{-3}; 5 cm^3). The layers were separated, and the organic layer was washed with water. The combined aqueous fractions were acidified with concentrated hydrochloric acid and extracted into dichloromethane (× 3). The combined extracts were dried ($MgSO_4$) and evaporated to yield the *acid* **52** (422.4 mg, 90%) as a foam, $[\alpha]_D^{25}$ −176.3 (*c* 0.40 in $CHCl_3$; 65% ee) (Found: M^+, 344.1203. $C_{19}H_{21}O_4P$ requires *M*, 344.1277); R_F(EtOAc–4% MeOH–0.5% AcOH) 0.36; $\nu_{max}(CHCl_3)/cm^{-1}$ 3400–2500 (OH), 1720 (C=O), 1440 (PPh) and 1150 (P=O); δ_H(250 MHz; $CDCl_3$) 8.54 (1 H, br s, CO_2H), 7.9–7.4 (10 H, m, Ph_2PO), 3.56 (1 H, ddd, *J* 7.0, 5.8 and 1.6, PCHCHO), 3.36 (1 H, fine m, $OCHCO_2H$), 2.22 (1 H, m, $CHMe_2$), 2.05 (1 H, ddd, *J* 9.1, 6.3 and 2.7, PCH), 1.07 (3 H, d, *J* 6.6, $CHMe_AMe_B$) and 1.04 (3 H, d, *J* 6.6, $CHMe_AMe_B$); δ_C(100 MHz; $CDCl_3$) 169.8$^-$ (CO_2H), 133–128 (Ph_2PO), 53.5$^+$ (PCHCHO), 53.4$^+$ ($^3J_{PC}$ 15.3, $OCHCO_2H$), 46.7$^+$ ($^1J_{PC}$ 66.4, PCH), 27.1$^+$ ($CHMe_2$), 23.9$^+$ ($^3J_{PC}$ 12.1, $CHMe_AMe_B$) and 18.9$^+$ ($CHMe_AMe_B$); *m*/*z* 344 (3.5%, M^+), 343 (3.5, M − H), 257 (42, $Ph_2POC_3H_4O$), 219 (33, Ph_2PO_2H), 202 (72, Ph_2POH) and 201 (100, Ph_2PO).

(2*S*,3*S*,4*R*)-4-Diphenylphosphinoyl-2,3-epoxy-5-methylhexanoic acid 55

In the same way, the epoxy alcohol[6] *anti*-**1e** (68.7 mg, 0.208 mmol) gave the *acid* **55** (65.1 mg, 91%) as needles, mp > 210 °C (from EtOAc–MeOH), $[\alpha]_D^{25}$ −31.7 (*c* 0.63 in $CHCl_3$; 85% ee) (Found: C, 66.15; H, 6.1; P, 9.0%; M^+, 344.1147. $C_{19}H_{21}O_4P$ requires C, 66.26; H, 6.15; P, 8.99%; *M*, 344.1178); R_F(EtOAc–4% MeOH–0.5% AcOH) 0.36; ν_{max}(Nujol)/cm^{-1} 3100–2400 (OH), 1720 (C=O), 1460 (PPh) and 1175 (P=O) δ_H(250 MHz; $CDCl_3$) 10.8 (1 H, br s, CO_2H), 7.9–7.4 (10 H, m, Ph_2PO), 3.76 (1 H, dd, *J* 8.5 and 1.8, PCHCHO), 2.50 (1 H, d, *J* 1.8, $OCHCO_2H$), 2.20 (1 H, m, $CHMe_2$), 2.05 (1 H, dt, *J* 2.5 and 8.5, PCH), 1.23 (3 H, d, *J* 7.0, $CHMe_AMe_B$) and 1.15 (3 H, d, *J* 7.0, $CHMe_AMe_B$); δ_C(100 MHz; $CDCl_3$) 169.5$^-$ (CO_2H), 133–128 (Ph_2PO), 53.3$^+$ ($^2J_{PC}$ 3.6, PCHCHO), 51.1$^+$ ($OCHCO_2H$), 47.6$^+$ ($^1J_{PC}$ 64.9, PCH), 28.1$^+$ ($CHMe_2$), 23.0$^+$ ($^3J_{PC}$ 14.6, $CHMe_AMe_B$) and 18.2$^+$ ($^3J_{PC}$ 1.5, $CHMe_AMe_B$); *m*/*z* 344 (3.5%, M^+), 257 (29, $Ph_2POC_3H_4O$), 219 (6, $Ph_2PO_2H_2$), 202 (70, Ph_2POH) and 201 (100, Ph_2PO).

(2*R*,3*R*,4*R*)-4-Cyclohexyl-4-diphenylphosphinoyl-2,3-epoxybutanoic acid 58

In the same way, the epoxy alcohol[6] *syn*-**1h** (273.1 mg, 0.737 mmol) gave the *acid* **58** (279.4 mg, 99%) as a powder, mp > 200 °C (decomp.) (from EtOAc–MeOH) (Found: M − CO_2, 340.1575. $C_{22}H_{25}O_4P$ requires M − CO_2, 340.1592); $\nu_{max}(CHCl_3)/cm^{-1}$ 3400–2500 (OH), 1720 (C=O), 1440 (PPh) and 1150 (P=O); δ_H(250 MHz; $CDCl_3$) 9.44 (1 H, br s, CO_2H), 7.9–7.4 (10 H, m, Ph_2PO), 3.57 (1 H, dd, *J* 7.6 and 6.6, PCHCHO), 3.33 (1 H, fine m, $OCHCO_2H$) and 2.2–1.0 [12 H, m, PCH and $CH(CH_2)_5$]; δ_C(100 MHz; $CDCl_3$) 169.8$^-$ (CO_2H), 133–128 (Ph_2PO), 53.9$^+$ (PCHCHO), 53.6$^+$ ($^3J_{PC}$ 11.0, $OCHCO_2H$), 47.1$^+$ ($^1J_{PC}$ 65.9, PCH), 37.4$^+$ [$CH(CH_2)_5$], 34.1$^-$, 29.7$^-$, 26.8$^-$, 26.6$^-$ and 25.7$^-$ [$CH(CH_2)_5$]; *m*/*z* 340 (95%, M − CO_2), 257 (75, $Ph_2POC_3H_4O$), 219 (38, Ph_2PO_2H), 202 (95, Ph_2POH) and 77 (100, Ph).

(2*R*,3*R*,4*S*)-4-Cyclohexyl-4-diphenylphosphinoyl-2,3-epoxybutanoic acid 61

In the same way, the epoxy alcohol[6] *anti*-**1h** (615.7 mg, 1.66 mmol) gave the *acid* **61** (491.3 mg, 77%) as prisms, mp > 220 °C (decomp.) (from EtOAc), $[\alpha]_D^{25}$ −108.6 (*c* 0.42 in $CHCl_3$; 63% ee) (Found: C, 68.5; H, 6.45; P, 7.9%; M + H, 385.1575. $C_{22}H_{25}O_4P$ requires C, 68.74; H, 6.55; P, 8.06%; M + H, 385.1569); R_F(EtOAc) 0.0; $\nu_{max}(CDCl_3)/cm^{-1}$ 3100–2400 (OH), 1720 (C=O), 1430 (PPh) and 1125 (P=O); δ_H(400 MHz; $CDCl_3$) 10.5 (1 H, br s, CO_2H), 7.9–7.4 (10 H, m, Ph_2PO), 3.74 (1 H, dd, *J* 8.7 and 1.4, PCHCHO), 2.49 (1 H, d, *J* 1.6, $OCHCO_2H$), 1.97 (1 H, dt, *J* 2.3 and 8.6, PCH) and 2.1–0.8 [11 H, m, $CH(CH_2)_5$]; δ_C(62.9 MHz; $CDCl_3$) 169.8$^-$ (CO_2H), 133–128 (Ph_2PO), 54.2$^+$ (PCHCHO), 52.0$^+$($OCHCO_2H$), 48.2$^+$ ($^1J_{PC}$ 67.0, PCH) and 39–26 [$CH(CH_2)_5$]; *m*/*z* (+FAB) 385 (100%, M + H) and 257 (28, $Ph_2POC_3H_4O$).

(2*R*,3*S*,4*S*)-2-Benzylamino-4-diphenylphosphinoyl-3-hydroxy-5-methylhexanoic acid 53

The epoxy acid **52** (422.4 mg, 1.227 mmol) dissolved in a mixture of water (2.5 cm^3) and benzylamine (2.5 cm^3) was heated under reflux for 24 h. The mixture was then diluted with water (30 cm^3), washed with diethyl ether (× 2) and acidified with concentrated hydrochloric acid. The amino acid **53** (163.7 mg, 47%), a powder, was filtered off; δ_H(250 MHz; CD_3OD) 7.9–7.4 (15 H, m, Ph_2PO and Ph), 4.75 (1 H, dd, *J* 21.0 and 4.4, CHOH), 4.45 (1 H, d, *J* 13.1, CH_AH_BN), 4.33 (1 H, d, *J* 13.1, CH_AH_BN), 3.75 (1 H, d, *J* 4.6, CHN), 3.04 (1 H, d, *J* 18.4, PCH), 2.20 (1 H, m, $CHMe_2$), 1.05 (3 H, d, *J* 6.5, $CHMe_AMe_B$) and 0.54 (3 H, d, *J* 6.5, $CHMe_AMe_B$), characterised as the methyl ester **64**.

(2*R*,3*S*,4*R*)-2-Benzylamino-4-diphenylphosphinoyl-3-hydroxy-5-methylhexanoic acid 56

In the same way, the epoxy acid **53** (92 mg, 0.267 mmol) gave the amino acid **56** (92.9 mg, 77%), which was characterised as the methyl ester **65**.

(2*R*,3*S*,4*R*)-2-Benzylamino-4-diphenylphosphinoyl-3-hydroxybutanoic acid 59

In the same way, the epoxy acid **58** (74.75 mg, 0.194 mmol) gave the amino acid **59** (38.2 mg, 40%), which was characterised as the methyl ester **66**.

(2*R*,3*S*,4*SR*)-2-Benzylamino-4-diphenylphosphinoyl-3-hydroxybutanoic acid 62

In the same way, the epoxy acid **61** (115.3 mg, 0.30 mmol) gave the amino acid **62** (74.5 mg, 51%); *m*/*z* (+FAB) 434 (85%), 219 (36, $Ph_2PO_2H_2$), 202 (35, Ph_2POH) and 201 (100, Ph_2PO), which was characterised as the methyl ester **67**.

Methyl (2*R*,3*S*,4*S*)-2-benzylamino-4-diphenylphosphinoyl-3-hydroxy-5-methylhexanoate 64

An ethereal solution of diazomethane (prepared by the method of Vogel[34]) was added to a solution of the epoxy acid **53** (45.0 mg, 0.100 mmol) in methanol (8 cm^3) until a yellow colour persisted. After 10 min, the solution was carefully quenched with saturated aqueous sodium hydrogen carbonate, diluted with water and extracted into dichloromethane (×3). The combined extracts were washed with brine, dried (Na_2SO_4) and evaporated to yield the *ester* **64** (48.0 mg, 103%) as an oil, $[\alpha]_D^{25}$ +54.4 (*c* 0.48 in $CHCl_3$; 65% ee) (Found: M − CO_2Me, 406.1932. $C_{27}H_{32}NO_4P$ requires *M* − CO_2Me, 406.1936); R_F(EtOAc) 0.56; ν_{max}(film)/cm^{-1} 3600–3200 (OH and NH), 1730 (C=O), 1440 (PPh) and 1175 (P=O); δ_H(400 MHz; $CDCl_3$) 8.0–7.2 (15 H, m, Ph_2PO and Ph), 4.08 (1 H, dt, *J* 23.8 and 8.8, C*H*OH), 3.64 (3 H, s, OMe), 3.30 (1 H, d, *J* 13.0, NCH_AH_BPh), 3.18 (1 H, d × fine m, *J* 10.2, PCH), 2.96 (1 H, d, *J* 9.6, CHN), 2.93 (1 H, d, *J* 12.5, NCH_AH_BPh), 2.08 (1 H, m, C*H*Me_2), 1.09 (3 H, d, *J* 6.9, CHMe_AMe_B) and 1.02 (3 H, d, *J* 6.9, CHMe_AMe_B); δ_C(62.9 MHz; $CDCl_3$) 175.7$^-$ (CO_2), 140–127 (Ph_2PO and Ph), 72.7$^+$ ($^2J_{PC}$ 5.2, CHOH), 65.8$^+$ (CHN), 51.68$^+$ (OMe), 51.65$^-$ (NCH_2Ph), 41.6$^+$ ($^1J_{PC}$ 65.8, PCH), 28.0$^+$ (*C*HMe_2), 22.7$^+$ ($^3J_{PC}$ 14.0, CHMe_AMe_B) and 19.2$^+$ (CHMe_AMe_B); *m*/*z* 406 (1%, M − CO_2Me), 287 (92, M − $PhCH_2NHCHCO_2Me$), 243 (28, $Ph_2POCHCHO$), 202 (26, Ph_2POH), 201 (100, Ph_2PO) and 91 (75, $PhCH_2$).

Methyl (2*R*,3*S*,4*R*)-2-benzylamino-4-diphenylphosphinoyl-3-hydroxy-5-methylhexanoate 65

In the same way, the amino acid **56** (19.3 mg, 0.0427 mmol) gave the *ester* **65** (20.5 mg, 102%) as an oil, $[\alpha]_D^{25}$ +14.8 (*c* 0.82 in $CHCl_3$; 85% ee) (Found: M − CO_2Me, 406.1907. $C_{27}H_{32}NO_4P$ requires *M* − CO_2Me, 406.1936); R_F(EtOAc) 0.54; ν_{max}(film)/cm^{-1} 3500–3200 (OH and NH), 1720 (C=O), 1435 (PPh) and 1175 (P=O); δ_H(400 MHz; $CDCl_3$) 7.9–7.2 (15 H, m, Ph_2PO and Ph), 4.3 (1 H, br s, NH), 4.08 (1 H, t, *J* 10.3, C*H*OH), 3.74 (1 H, d, *J* 13.0, NCH_AH_BPh), 3.70 (3 H, s, OMe), 3.57 (1 H, d, *J* 13.0, NCH_AH_BPh), 3.44 (1 H, d, *J* 9.8, CHN), 3.03 (1 H, d, *J* 8.4, PCH), 2.18 (1 H, dd × septet, *J* 14.0, 1.4 and 7.0, C*H*Me_2), 1.12 (3 H, d, *J* 7.1, CHMe_AMe_B) and 0.83 (3 H, d, *J* 7.2, CHMe_AMe_B); δ_C(100 MHz; $CDCl_3$) 175.6$^-$ (CO_2), 139–127 (Ph_2PO and Ph), 73.5$^+$ (CHOH), 62.6$^+$ ($^3J_{PC}$ 11.6, CHN), 52.0$^+$ (OMe and NCH_2Ph), 42.8$^+$ ($^1J_{PC}$ 68.5, PCH), 25.7$^+$ (*C*HMe_2), 24.4$^+$ (CHMe_AMe_B) and 22.2$^+$ ($^3J_{PC}$ 8.2, CHMe_AMe_B); *m*/*z* 406 (2%, M − CO_2Me), 376 (10, M − $PHCH_2$), 287 (81, M − $PhCH_2NHCHCO_2Me$), 243 (24, $Ph_2POCHCHO$), 202 (30, Ph_2POH), 201 (100, Ph_2PO) and 91 (88, $PhCH_2$).

Methyl (2*R*,3*S*,4*R*)-2-benzylamino-4-diphenylphosphinoyl-3-hydroxy-5-methylhexanoate 66

In the same way, the amino acid **58** (7.9 mg, 0.0161 mmol) gave the *ester* **66** (8.3 mg, 102%) as an oil, $[\alpha]_D^{25}$ −40.7 (*c* 0.08 in $CHCl_3$; 63% ee); R_F(EtOAc) 0.50; δ_H(400 MHz; $CDCl_3$) 7.9–7.1 (15 H, m, Ph_2PO and Ph), 5.65 (1 H, br s, NH), 4.02 (1 H, dd, *J* 25.1 and 10.2, C*H*OH), 3.60 (3 H, s, OMe), 3.26 (1 H, d, *J* 13.0, NCH_AH_BPh), 3.11 (1 H, d × fine m, *J* 10.6, PCH), 2.95 (1 H, d, *J* 10.3, CHN), 2.88 (1 H, d, *J* 12.9, NCH_AH_BPh) and 2.0–0.6 [11 H, m, $CH(CH_2)_5$]; δ_C(100 MHz; $CDCl_3$) 178.7$^-$ (CO_2), 140–127 (Ph_2PO and Ph), 73.5$^+$ ($^2J_{PC}$ 5.2, CHOH), 65.8$^+$ (CHN), 51.68$^+$ (OMe), 51.66$^-$ (NCH_2Ph), 42.2$^+$ ($^1J_{PC}$ 72, PCH), 38.7$^+$ [*C*H$(CH_2)_5$], 32.9$^-$ ($^3J_{PC}$ 13.0), 29.8$^-$, 27.0$^-$, 26.8$^-$ and 25.8$^-$ [CH$(CH_2)_5$].

Methyl (2*R*,3*S*,4*S*)-2-benzylamino-4-diphenylphosphinoyl-3-hydroxybutanoate 67

In the same way, the amino acid **62** (9.2 mg, 0.0187 mmol) gave the *ester* **67** (9.4 mg, 100%) as an oil, $[\alpha]_D^{25}$ +14.4 (*c* 0.94 in $CDCl_3$; 75% ee); R_F(EtOAc) 0.48; δ_H(400 MHz; $CDCl_3$) 7.9–7.2 (15 H, m, Ph_2PO and Ph), 4.3 (1 H, br s, NH), 4.06 (1 H, t, *J* 10.4, C*H*OH), 3.75 (1 H, d, *J* 13.0, NCH_AH_BPh), 3.72 (3 H, s, OMe), 3.54 (1 H, d, *J* 13.0, NCH_AH_BPh), 3.44 (1 H, d, *J* 9.8, CHN), 2.94 (1 H, d, *J* 8.4, PCH) and 2.1–0.6 [11 H, m, $CH(CH_2)_5$]; δ_C(100 MHz; $CDCl_3$) 175.6$^-$ (CO_2H), 139–127 (Ph_2PO and Ph), 73.6$^+$ (CHOH), 62.4$^+$ ($^3J_{PC}$ 12.0, CHN), 52.0$^+$ (OMe), 51.9$^-$ (NCH_2Ph), 43.1$^+$ ($^1J_{PC}$ 68.3, PCH), 36.5$^+$ [*C*H$(CH_2)_5$], 34.5$^-$, 32.7$^-$ ($^3J_{PC}$ 8.6), 27.4$^-$, 27.2$^-$ and 25.9$^-$ [CH$(CH_2)_5$].

Methyl (*R*,*E*)-2-benzylamino-5-methylhex-3-enoate 54

Sodium hydride (60% suspension; 13 mg, 0.325 mmol, 4 equiv.) was added to a stirred suspension of the amino acid **53** (34.4 mg, 0.076 mmol) in dry DMF (2 cm^3) under nitrogen and the mixture was heated to 60 °C. It rapidly cleared and after 20 min gave a thick white precipitate. After a total of 30 min at 60 °C, the mixture was allowed to cool to room temperature, after which it was carefully quenched with a minimum amount (5 drops) of saturated aqueous ammonium chloride and diluted with ethanol (5 cm^3). An ethereal solution of diazomethane (prepared according to Vogel[34]) was then added to the mixture until a yellow colour persisted. After 10 min excess of diazomethane present in the mixture was carefully quenched by the addition of saturated aqueous sodium hydrogen carbonate. After dilution with water, the mixture was extracted with ether (×3) and the combined extracts were washed with water (×2), dried (Na_2SO_4) and evaporated under reduced pressure. Purification of the residue by PLC, eluting with hexane–EtOAc (4:1), gave the *amino ester* **54** (13.15 mg, 70%) as an oil, $[\alpha]_D^{25}$ −30.4 (*c* 0.57 in $CDCl_3$) (Found: M − CO_2Me, 188.1434. $C_{15}H_{21}NO_2$ requires *M* − CO_2Me, 188.1439); R_F[hexane–EtOAc (4:1)] 0.27; ν_{max}($CHCl_3$)/cm^{-1} 1720 (C=O); δ_H(250 MHz; $CDCl_3$) 7.4–7.2 (5 H, m, Ph), 5.70 (1 H, dd, *J* 15.5 and 6.4, CH=C*H*CHMe_2), 5.37 (1 H, ddd, *J* 15.5, 7.3 and 1.2, NCHC*H*=CH), 3.81 (1 H, d, *J* 7.2, CHN), 3.73 (2 H, s, NCH_2Ph), 3.72 (3 H, s, OMe), 3.30 (1 H, octet, *J* 6.7, C*H*Me_2), 0.989 (3 H, d, *J* 6.7, CHMe_AMe_B) and 0.984 (3 H, d, *J* 6.7, CHMe_AMe_B); δ_C(100 MHz; $CDCl_3$) 173.8$^-$ (CO_2), 142.3$^+$ (CH=CHCHN), 139.4$^-$ (Ph *ipso*), 128.4$^+$, 128.3$^+$ (Ph *ortho* and *meta*), 127.1$^+$ (Ph *para*), 123.1$^+$ (NCHCH=*C*H), 62.6$^+$ (CHN), 52.0$^+$ (OMe), 51.2$^-$ (CH_2N), 30.9$^+$ (*C*HMe_2), 22.08$^+$ (CHMe_AMe_B) and 22.06$^+$ (CHMe_AMe_B); *m*/*z* 188 (100%, M − CO_2Me) and 91 (92, $PhCH_2$). The ^1H NMR spectrum of this material in the presence of 1-(9-anthryl)-2,2,2-trifluoroethanol[24] indicated an enantiomeric excess of 63%.

Methyl (*S*,*E*)-2-benzylamino-4-cyclohexylbut-3-enoate 60

In the same way, the amino acid **59** (38.2 mg, 0.0777 mmol) gave, after purification by PLC, eluting with Et_2O–hexane (3:2), the *amino ester* **60** (11.4 mg, 51%) as an oil, $[\alpha]_D^{25}$ +20.8 (*c* 0.39 in $CDCl_3$; 63% ee) (Found: M + H, 288.1977. $C_{18}H_{25}NO_2$ requires *M* + H, 288.1963); R_F[Et_2O–hexane (3:2)] 0.48; ν_{max}($CDCl_3$)/cm^{-1} 1720 (C=O); δ_H(400 MHz; $CDCl_3$) 7.25–7.15 (5 H, m, Ph), 5.62 (1 H, dd, *J* 15.4 and 6.6, NCHCH=C*H*CH), 5.32 (1 H, dd, *J* 15.5 and 7.4, NCH-C*H*=CHCH), 3.75 (1 H, d, *J* 7.4, CHN), 3.67 (2 H, s, NCH_2Ph), 3.66 (3 H, s, OMe) and 2.0–0.9 [11 H, m, $CH(CH_2)_5$]; *m*/*z* (+ FAB) 288 (100%, M + H) and 136 (100, M − H − CO_2Me − $PhCH_2$).

Methyl (*R*,*Z*)-2-benzylamino-5-methylhex-3-enoate 57

Powdered potassium hydroxide (85%; 15 mg, 0.25 mmol, 7 equiv.) was added to a stirred suspension of the amino acid **56** (15.6 mg, 0.0346 mmol) in dry DMSO (2 cm^3) under nitrogen and the mixture was heated to 60 °C. It rapidly cleared and after 5 h was allowed to cool to room temperature. At this point it was carefully quenched with a minimum amount (5 drops) of saturated aqueous ammonium chloride, and diluted with

ethanol (5 cm^3). An ethereal solution of diazomethane (prepared according to the method of Vogel[34]) was added to the mixture until a yellow colour persisted. After 10 min, the excess of diazomethane present in the mixture was carefully quenched by the addition of saturated aqueous sodium hydrogen carbonate. After dilution with water the mixture was extracted with ether (×3) and the combined extracts were washed with water (×2), dried (Na_2SO_4) and evaporated under reduced pressure. Purification of the residue by PLC, eluting with [hexane–EtOAc (4:1)] gave the *amino ester* **57** (5.85 mg, 68%) as an oil, $[\alpha]_D^{25}$ +44.6 (*c* 0.24 in $CDCl_3$; 65%) (Found: M + H, 248.1667. $C_{15}H_{21}NO_2$ requires M + H, 248.1650); R_F [hexane–EtOAc (4:1)] 0.24; $\nu_{max}(CDCl_3)/cm^{-1}$ 1725 (C=O); δ_H(400 MHz; $CDCl_3$) 7.4–7.2 (5 H, m, Ph), 5.48 (1 H, t, *J* 10.6, CH=C*H*CHMe$_2$), 5.15 (1 H, t, *J* 10.2, NCHC*H*=CH), 4.15 (1 H, d, *J* 9.1, CHN), 3.74 (2 H, AB m, NCH_2Ph), 3.70 (3 H, s, OMe), 2.57 (1 H, d × septet, *J* 9.6 and 6.6, C*H*Me$_2$), 0.95 (3 H, d, *J* 6.6, CH*Me*$_A$Me$_B$) and 0.94 (3 H, d, *J* 6.7, CHMe$_A$*Me*$_B$); δ_C(100 MHz; $CDCl_3$) (no APT) 173.8 (CO_2), 142.7 (CH=*C*HCHN), 139.5 (Ph *ipso*), 128.4, 128.3 (Ph *ortho* and *meta*), 127.2 (Ph *para*), 123.7$^+$ (NCHCH=*C*H), 57.9 (CHN), 52.2 (OMe), 51.2 (CH_2N), 29.5 (*C*HMe$_2$), 27.4 (CH*Me*$_A$Me$_B$) and 21.9 (CHMe$_A$*Me*$_B$); *m/z* (+ FAB) 248 (100%, M + H) and 188 (75, M − CO_2Me). The ^1H NMR spectrum of this material in the presence of 1-(9-anthryl)-2,2,2-trifluoroethanol[24] indicated an enantiomeric excess of 60–70%.

Methyl (*S,Z*)-2-benzylamino-4-cyclohexylbut-3-enoate 63

In the same way, the amino acid **62** (46.8 mg, 0.095 mmol) gave, after purification by PLC, eluting with Et_2O–hexane (3:2), the *amino ester* **63** (10.5 mg, 38%) as an oil, $[\alpha]_D^{25}$ +50.2 (*c* 1.05 in $CDCl_3$; 75% ee) (Found: M + H, 288.1957. $C_{18}H_{25}NO_2$ requires *M* + H, 288.1963); R_F[Et_2O–hexane (3:2)] 0.48; $\nu_{max}(CDCl_3)/cm^{-1}$ 1720 (C=O); δ_H(400 MHz; $CDCl_3$) 7.4–7.2 (5 H, m, Ph), 5.49 (1 H, t, *J* 10.2, NCHCH=C*H*CH), 5.17 (1 H, t, *J* 10.1, NCHC*H*=CHCH), 4.14 (1 H, d, *J* 9.2, CHN), 3.74 (2 H, AB m, NCH_2Ph), 3.70 (3 H, s, OMe) and 2.0–0.9 [11 H, m, CH(CH_2)$_5$]; δ_C(100 MHz; $CDCl_3$) 173.7$^-$ (CO_2), 141.4$^+$ (CH=*C*HCHN), 139.3$^-$ (Ph *ipso*), 128.4$^+$, 128.3$^+$ (Ph *ortho* and *meta*), 127.2$^+$ (Ph *para*), 123.8$^+$ (NCHCH=*C*H), 57.7$^+$ (CHN), 52.1$^+$ (OMe), 51.0$^-$ (CH_2N), 37.0$^+$ [*C*H–(CH_2)$_5$–], 33.0$^-$, 32.8$^-$, 25.9$^-$, 25.7$^-$ and 25.6$^-$ [(CH_2)$_5$]; *m/z* (+FAB) 288 (100%, M + H) and 228 (20, M − CO_2Me).

Attempted Horner–Wittig elimination of the ester 64

A mixture of sodium hydride (60% suspension; 12 mg, 3 mmol, 2.8 equiv.) and the amino ester **64** (50.7 mg, 0.109 mmol) dissolved in dry DMF (2 cm) was heated under nitrogen at 60 °C for 90 min. After the work-up procedure described for compound **54**, purification of the product by PLC, eluting with hexane–EtOAc (2:1), gave 2-diphenylphosphinoyl-3-methylbutanal **68** (7 mg, 22%) as an oil (Found: M$^+$, 286.1146. $C_{17}H_{19}O_2P$ requires *M*, 286.1122); R_F(EtOAc) 0.45; $\nu_{max}(CHCl_3)/cm^{-1}$ 1710 (C=O), 1440 (PPh) and 1165 (P=O); δ_H(400 MHz; $CDCl_3$) 9.69 (1 H, d, *J* 5.2, CHO), 7.9–7.2 (10 H, m, Ph_2PO and Ph), 3.24 (1 H, dt, *J* 10.1 and 5.5, PCH), 2.54 (1 H, m, C*H*Me$_2$), 1.19 (3 H, d, *J* 6.9, CH*Me*$_A$Me$_B$) and 1.00 (3 H, d, *J* 6.9, CHMe$_A$*Me*$_B$); *m/z* 286 (3.5%, M$^+$), 271 (13, M − Me), 258 (11, M − CO), 243 (74, $Ph_2POC_3H_7$), 202 (42, Ph_2POH) and 201 (100, Ph_2PO).

Attempted Payne rearrangement–nucleophilic ring-opening of the epoxy alcohol 69

A solution of 1,1-dimethylethanethiol (0.05 cm^3, 0.444 mmol, 1.3 equiv.) in *tert*-butyl alcohol (0.5 cm^3) was added dropwise over a period of 50 min to a vigorously stirred solution of the epoxy alcohol **69** (100 mg, 0.331 mmol) in a mixture of 0.5 mol dm^{-3} aqueous sodium hydroxide (1.5 cm^3) and *tert*-butyl alcohol (1.5 cm^3) at 72 °C under nitrogen. Near the end of the addition, the cloudy reaction mixture cleared. After the mixture had cooled to room temperature, saturated aqueous ammonium chloride (5 cm^3) was added to it followed by sufficient water to clear the aqueous layer. The layers were separated, and the aqueous layer was extracted with dichloromethane (5 × 4 cm^3). The combined organic fractions were washed with saturated aqueous ammonium chloride, dried (Na_2SO_4) and evaporated under reduced pressure to give a crude yellow oil (144 mg). The ^1H NMR spectrum of this crude product showed it to contain 52% of the (*E*)-vinyl phosphine oxide **72**, 19% of the (*Z*)-vinyl phosphine oxide **73**, and 17% of the allylic phosphine oxide **74** (by integration of distinctive signals relative to the Ph_2PO 10 H m), plus some 1,1-dimethylethanethiol and *tert*-butyl alcohol. Assignments were made tentatively from the ^1H NMR spectrum of the crude reaction mixture and by comparison with the spectra of the pure *E*- and *Z*-vinyl phosphine oxides obtained in other experiments:

(*R,E*)-4-Diphenylphosphinoyl-3-methylbut-3-ene-1,2-diol **72** had R_F(EtOAc) 0.05; δ_H(400 MHz; $CDCl_3$) 7.8–7.3 (10 H, m, Ph_2PO), 6.38 (1 H, d, *J* 25.1, PCH), 4.18 (1 H, dd, *J* 5.6 and 4.5, C*H*OH), 3.78 (1 H, dd, *J* 11.3 and 4.1, CH_AH$_B$OH), 3.59 (1 H, dd, *J* 5.8 and 11.3, CH$_A$$H_B$OH) and 1.90 (3 H, d, *J* 1.8, Me); δ_C(100 MHz; $CDCl_3$) 162.6$^-$ (*C*Me), 135–128 (Ph_2PO), 117.2$^+$ ($^1J_{PC}$ 100.5, PC), 77.0$^+$ (*C*HOH), 64.8$^-$ (CH_2OH) and 17.7$^+$ (Me). Irradiation of the signal at δ 6.38 gave no NOE at δ 1.90.

(*R,Z*)-4-Diphenylphosphinoyl-3-methylbut-3-ene-1,2-diol **73** had R_F(EtOAc) 0.13; δ_H(400 MHz; $CDCl_3$) 7.8–7.3 (10 H, m, Ph_2PO), 5.96 (1 H, d, *J* 23.8, PCH), 4.53 (1 H, t, *J* 5.3, C*H*OH), 3.75 (2 H, ABX m, CH_2OH) and 2.06 (3 H, s, Me); δ_C(100 MHz; $CDCl_3$) 163.0$^-$ (*C*Me), 135–128 (Ph_2PO), 120.2$^+$ ($^1J_{PC}$ 102.5, PC), 75.3$^+$ (*C*HOH), 65.4$^-$ (CH_2OH) and 25.0$^+$ (Me). Irradiation of the signal at δ 5.96 gave a NOE at δ 2.06.

Signals due to the allylic phosphine oxide **74**: δ_H(250 MHz; $CDCl_3$) 7.8–7.3 (10 H, m, Ph_2PO), 5.04 (1 H, d, *J* 5.5, C=CH_AH$_B$), 4.53 (1 H, d, *J* 5.5, C=CH$_A$$H_B$), 4.27 (1 H, m, C*H*OH), 3.35 (1 H, t, *J* 14.5, PCH_AH$_B$) and 3.23 (1 H, t, *J* 14.5, PCH$_A$$H_B$).

(2*S*,3*R*)-4-Diphenylphosphinoyl-2,3-epoxy-3-methylbutyl methanesulfonate 75

Methanesulfonyl chloride (0.38 cm^3, 4.8 mmol, 2 equiv.) and triethylamine (0.51 cm^3, 3.6 mmol, 1.5 equiv.) were added dropwise to a stirred solution of the epoxy alcohol[6] **69** (734.4 mg, 2.432 mmol) in dry dichloromethane (10 cm^3) at 0 °C under nitrogen. After 15 min, the reaction mixture was poured into dichloromethane (100 cm^3) and washed with water (2 × 20 cm^3). The aqueous layer was extracted with dichloromethane, and the combined organic fractions were washed with brine (20 cm^3), dried (Na_2SO_4) and evaporated. Purification of the crude product by flash chromatography, eluting with EtOAc, gave the *epoxy mesylate* **75** (861.3 mg, 93%) as needles, mp 128–129 °C (from CH_2Cl_2–Et_2O), $[\alpha]_D^{25}$ −25.9 (*c* 1.47 in $CHCl_3$; 97% ee) (Found: C, 56.7; H, 5.7; P, 8.3%; M − SO_2Me, 301.0992. $C_{18}H_{21}O_5PS$ requires C, 56.8; H, 5.56; P, 8.14%; *M* − SO_2Me, 301.0994); R_F(EtOAc) 0.21; $\nu_{max}(CHCl_3)/cm^{-1}$ 1440 (PPh), 1350 (S=O) and 1150 (P=O); δ_H(250 MHz, $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 4.18 (1 H, dd, *J* 11.9 and 3.8, CH_AH$_B$O), 4.06 (1 H, dd, *J* 11.8 and 7.2, CH$_A$$H_B$O), 3.02 (3 H, s, SO_2Me), 2.99 (1 H, dd, *J* 7.6 and 4.0, OC*H*CH_2O), 2.91 (1 H, dd, *J* 15.0 and 12.3, PCH_AH$_B$), 2.30 (1 H, dd, *J* 14.6 and *J* 11.5, PCH$_A$$H_B$) and 1.42 (3 H, s, CMe); δ_C(100 MHz, $CDCl_3$) 134–128 (Ph_2PO), 68.1$^-$ (CH_2O), 59.3$^+$ (OC*H*CH_2O), 57.9$^-$ (*C*Me), 39.9$^-$ ($^1J_{PC}$ 66.4, PCH_2), 37.8$^+$ (SO_2Me) and 19.1$^+$ (*CMe*); *m/z* 301 (1.4%, M − SO_2Me), 284 (17, M − OSO_2Me), 271 (16, M − CH_2O-SO_2Me), 202 (44, Ph_2POH) and 201 (100, Ph_2PO).

(2*S*,3*S*)-4-Diphenylphosphinoyl-2,3-epoxy-3-methylbutyl methanesulfonate 78

In the same way, the epoxy alcohol[6] **77** (752.3 mg, 2.49 mmol) gave, after purification by flash chromatography, eluting with EtOAc, the *epoxy mesylate* **78** (935.7 mg, 99%) as minute needles, mp 117.5–119 °C (from EtOAc), $[\alpha]_D^{25}$ −62.1 (*c* 1.16 in $CHCl_3$; 97% ee) (Found: C, 56.7; H, 5.56; P, 8.15%; M^+, 380.0867. $C_{17}H_{19}O_3P$ requires C, 56.8; H, 5.56; P, 8.14%; *M*, 380.0847); R_F(EtOAc) 0.31; $\nu_{max}(CHCl_3)/cm^{-1}$ 1440 (PPh), 1340 (S=O) and 1150 (P=O); δ_H(250 MHz; $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 4.52 (1 H, dd, *J* 12.2 and 2.8, CH_AH_BO), 4.09 (1 H, dd, *J* 12.2 and 8.3, CH_AH_BO), 3.12 (1 H, dd, *J* 8.3 and 2.8, $OCHCH_2OH$), 3.05 (3 H, s, SO_2Me), 2.88 (1 H, dd, *J* 15.0 and 9.2, PCH_AH_B), 2.45 (1 H, t, *J* 15.0, PCH_AH_B) and 1.27 (3 H, s, Me); δ_C(100 MHz, $CDCl_3$) 134–128 (Ph_2PO), 69.3$^-$ (CH_2O), 60.7$^+$ ($OCHCH_2O$), 58.3$^-$ (*C*Me), 37.9$^+$ (SO_2Me), 35.6$^-$ ($^2J_{PC}$ 66.1, PCH_2) and 24.5$^+$ (*CMe*); *m*/*z* 380 (3.5%, M^+), 301 (3, M − SO_2Me), 284 (32, M − $MeSO_3H$), 271 (18, M − CH_2OSO_2Me), 202 (38, Ph_2POH) and 201 (100, Ph_2PO).

(2*S*,3*R*)-4-Diphenylphosphinoyl-2,3-epoxybutyl methanesulfonate 82

In the same way, the epoxy alcohol[6] **81** gave, after purification of the crude product by flash chromatography, eluting with EtOAc–4% MeOH, the *epoxy mesylate* **82** (1.358 g, 75%) as minute needles, mp 118.5–120.5 °C (from EtOAc), $[\alpha]_D^{25}$ −18.6 (*c* 2.09 in $CHCl_3$; 82% ee) (Found: C, 55.8; H, 5.2; P, 8.4%; M − $MeSO_3H$, 270.0796. $C_{17}H_{19}O_5PS$ requires C, 55.73; H, 5.23; P, 8.45%; *M* − $MeSO_3H$, 270.0810); R_F(EtOAc) 0.15; $\nu_{max}(CHCl_3)/cm^{-1}$ 1440 (PPh), 1380 (S=O) and 1145 (P=O); δ_H(400 MHz; $CDCl_3$) 7.8–7.3 (10 H, m, Ph_2PO), 4.26 (1 H, dd, *J* 12.1 and 2.6, CH_AH_BO), 3.90 (1 H, dd, *J* 12.1 and 6.5, CH_AH_BO), 3.21 (1 H, m, PCH_2CHO), 3.01 (1 H, fine m, $OCHCH_2O$), 2.96 (3 H, s, Me), 2.81 (1 H, ddd, *J* 14.6, 11.0 and 5.3, PCH_AH_B) and 2.36 (1 H, ddd, *J* 14.6, 13.3 and 6.8, PCH_AH_B); δ_C(100 MHz; $CDCl_3$) 133–128 (Ph_2PO), 69.0$^-$ (CH_2O), 55.3$^+$ ($^3J_{PC}$ 5.3, $OCHCH_2O$), 50.7$^+$ (PCH_2CHO), 37.7$^-$ (Me) and 33.1$^-$ ($^1J_{PC}$ 67.3, PCH_2); *m*/*z* 270 (15%, M − $MeSO_3H$), 215 (5, Ph_2POCH_2), 202 (92, Ph_2POH) and 201 (100, Ph_2PO).

(2*S*,3*S*)-4-Diphenylphosphinoyl-2,3-dihydroxy-3-methylbutyl methanesulfonate 76

A solution of perchloric acid (72%; 0.70 cm^3, 5.0 mmol, 2.2 equiv.) in water (7.5 cm^3) was added to a stirred solution of the epoxy mesylate **75** (861.3 mg, 2.27 mmol) in DMSO (17.5 cm^3). Stirring was continued at room temperature under nitrogen for 7 days after which the reaction mixture was partitioned between brine (100 cm^3) and ethyl acetate (100 cm^3), and diluted with water to clear the aqueous layer. The aqueous layer was extracted into ethyl acetate (6 × 20 cm^3) and the combined organic fractions were washed with brine (50 cm^3), dried (Na_2SO_4) and evaporated under reduced pressure gave a crude product (1.06 g). This was purified by flash chromatography, eluting with EtOAc–2% MeOH, to yield the *mesylate* **76** (825.3 mg, 92%) as minute needles, mp 116–118 °C (from EtOAc–hexane), $[\alpha]_D^{25}$ −14.8 (*c* 1.78 in $CHCl_3$; >95% ee) (Found: M − $MeSO_3H$ − H_2O, 284.0973. $C_{18}H_{23}O_6PS$ requires *M* − CH_6O_4S, 284.0980); R_F(EtOAc) 0.27; $\nu_{max}(CHCl_3)/cm^{-1}$ 3310 (OH), 1440 (PPh), 1350 (S=O) and 145 (P=O); δ_H(250 MHz, $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 4.45 (1 H, dd, *J* 10.8 and 2.7, CH_AH_BO), 4.29 (1 H, dd, *J* 10.8 and 7.5, CH_AH_BO), 3.81 (1 H, dd, *J* 7.5 and 2.7, *CH*OH), 3.05 (3 H, s, SO_2Me), 2.80 (1 H, dd, *J* 15.3 and 12.0, PCH_AH_B), 2.55 (1 H, dd, *J* 15.2 and 8.9, PCH_AH_B) and 1.23 (3 H, d, *J* 1.3, CMe); δ_C(100 MHz, $CDCl_3$) 134–128 (Ph_2PO), 75.7$^+$ ($^3J_{PC}$ 6.5, CHOH), 74.2$^-$ ($^2J_{PC}$ 5.5, *C*Me), 70.9$^-$ (CH_2O), 37.5$^+$ (SO_2Me), 37.3$^-$ ($^1J_{PC}$ 69.0, PCH_2) and 25.2$^+$ ($^3J_{PC}$ 7.3, *CMe*); *m*/*z* 284 (3.5%, M − HSO_3Me − H_2O), 259 [45, $Ph_2POCH_2C(OH)Me$], 215 (45, Ph_2POCH_2), 202 (44, Ph_2POH) and 201 (100, Ph_2PO).

(2*S*,3*R*)-4-Diphenylphosphinoyl-2,3-dihydroxy-3-methylbutyl methanesulfonate 79

In the same way, the epoxy mesylate **78** (935.7 mg, 2.36 mmol) gave, after 45 h, a crude product (1.32 g) which was purified by flash chromatography, eluting with EtOAc–2% MeOH, to yield the *mesylate* **79** (756.4 mg, 77%) as an oil, $[\alpha]_D^{25}$ +57.4 (*c* 1.81 in $CHCl_3$; 73% ee) (Found: M − $HOCHCH_2OSO_2Me$, 259.0678. $C_{18}H_{23}O_6PS$ requires *M* − $HOCHCH_2OSO_2Me$, 259.0688); R_F(EtOAc) 0.28; $\nu_{max}(CHCl_3)/cm^{-1}$ 3280 (OH), 1440 (PPh), 1350 (S=O) and 1140 (P=O); δ_H(250 MHz, $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 4.41 (1 H, dd, *J* 10.8 and 3.0, CH_AH_BO), 4.25 (1 H, dd, *J* 10.8 and 7.8, CH_AH_BO), 3.85 (1 H, dd, *J* 7.7 and 3.0, *CH*OH), 3.04 (3 H, s, SO_2Me), 2.69 (2 H, ABP m, PCH_2) and 1.18 (3 H, s, CMe); δ_C(100 MHz, $CDCl_3$) 134–128 (Ph_2PO), 75.1$^+$ ($^3J_{PC}$ 6.3, CHOH), 74.1$^-$ ($^2J_{PC}$ 4.2, CMe), 70.6$^-$ (CH_2O), 38.3$^+$ ($^1J_{PC}$ 68.3, PCH_2), 37.6 (SO_2Me) and 25.9$^+$ ($^3J_{PC}$ 4.8, *C*Me); *m*/*z* 259 [66%, $Ph_2POCH_2C(OH)Me$], 216 (22, Ph_2POMe), 215 (55, Ph_2POCH_2), 202 (49, Ph_2POH) and 201 (100, Ph_2PO).

(2*S*,3*S*)-4-Diphenylphosphinoyl-2,3-dihydroxybutyl methanesulfonate 83

Water (3.5 cm^3) and perchloric acid (72%; 0.39 cm^3, 2.8 mmol, 2 equiv.) were added to a solution of the epoxy mesylate **82** (508.34 mg, 1.39 mmol) in THF (11.5 cm^3) and the mixture was heated under reflux for 42 h. After cooling to room temperature, the mixture was diluted with water (14 cm^3) and evaporated under reduced pressure to remove the THF. The resulting aqueous suspension was extracted with ethyl acetate (3 × 10 cm^3). The combined extracts were dried (Na_2SO_4) and evaporated under reduced pressure and the residue was purified by flash chromatography, eluting with EtOAc–8% MeOH to give the *mesylate* **83** (262.05 mg, 49%) as a foam; $[\alpha]_D^{25}$ +1.1 (*c* 1.59 in $CHCl_3$; 35% ee) (Found: M − $MeSO_3CH_2CHOH$, 245.0743. $C_{17}H_{19}O_5PS$ requires *M* − $MeSO_3C_2H_3O$, 245.0732); R_F(EtOAc–10% MeOH) 0.46; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3150 (OH), 1440 (PPh), 1360 (S=O) and 1145 (P=O); δ_H(250 MHz; CD_3OD) 7.8–7.4 (10 H, m, Ph_2PO), 4.40 (1 H, dd, *J* 10.6 and 2.9, CH_AH_BO), 4.22 (1 H, dd, *J* 10.5 and 6.0, CH_AH_BO), 3.99 (1 H, ddt, *J* 7.0, 2.8 and 10.0, PCH_2CHOH), 3.73 (1 H, ddd, *J* 7.1, 6.3 and 2.9, $CHOHCH_2O$), 3.06 (3 H, s, Me), 2.90 (1 H, ddd, *J* 15.3, 12.0 and 2.8, PCH_AH_B) and 2.63 (1 H, dt, *J* 15.4 and 9.8, PCH_AH_B); δ_C(100 MHz; $CDCl_3$–CD_3OD) 135–129 (Ph_2PO), 74.2$^+$ ($^3J_{PC}$ 11.9, *C*HOHCH$_2$O), 72.4$^-$ (CH_2O), 68.1$^+$ (PCH_2CHOH), 37.2$^-$ (Me) and 34.1$^-$ ($^1J_{PC}$ 72.6, PCH_2); *m*/*z* 245 (18%, M − $MeSO_3C_2H_3O$), 215 (20, Ph_2POCH_2), 202 (38, Ph_2POH), 201 (75, Ph_2PO) and 55 (100).

(2*S*,3*S*)-1-Diphenylphosphinoyl-3,4-epoxy-2-methylbutan-2-ol 70

Potassium carbonate (540 mg, 3.8 mmol, 2 equiv.) was added to a stirred solution of the mesylate **76** (796.8 mg, 2.0 mmol) in dry methanol (20 cm^3) under nitrogen to give, after a few minutes, a thick white precipitate. After 20 min, the reaction mixture was diluted with ethyl acetate (100 cm^3) and washed with water (2 × 20 cm^3). The aqueous fractions were extracted with ethyl acetate, and the combined organic fractions dried (Na_2SO_4) and evaporated under reduced pressure. Purification of the residue by flash chromatography yielded the *terminal epoxide* **70** (592 mg, 98%) as an oil, $[\alpha]_D^{25}$ −11.2 (*c* 1.01 in $CHCl_3$) (Found: M^+, 302.1064. $C_{17}H_{19}O_3P$ requires *M*, 302.1072); R_F(EtOAc) 0.25; $\nu_{max}(CHCl_3)/cm^{-1}$ 3350 (OH), 1435 (PPh) and 1150 (P=O); δ_H(250 MHz; $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 2.84–2.76 [2 H, m, $CH(O)CH_{pro\text{-}R}H_{pro\text{-}S}$], 2.69 (1 H, dd, *J* 15.2 and 9.2, PCH_AH_B), 2.58 (1 H, dd, *J* 15.2 and 11.0, PCH_AH_B), 2.35 (1 H, dd, *J* 4.8 and 4.0, $CH_{pro\text{-}R}H_{pro\text{-}S}O$) and 1.28 (3 H, d, *J*

1.2, Me); δ_C(100 MHz; $CDCl_3$) 134–128 (Ph_2PO), 70.8$^-$ ($^2J_{PC}$ 4.9, COH), 58.1$^+$ [$^3J_{PC}$ 7.2, *C*H(O)CH_2], 45.1$^-$ (CH_2O), 38.1$^-$ ($^1J_{PC}$ 69.5, PCH_2) and 26.8$^+$ ($^3J_{PC}$ 8.3, Me); *m/z* 302 (0.7%, M^+), 284 (19, M − H_2O), 259 (68, M − C_2H_3O), 216 (23, Ph_2POMe), 215 (61, Ph_2POCH_2), 202 (65, Ph_2POH) and 201 (100, Ph_2PO). The ^{1}H NMR spectrum of this material in the presence of 1-(9-anthryl)-2,2,2-trifluoroethanol[24] showed an enantiomeric excess of >95%.

(2*R*,3*S*)-1-Diphenylphosphinoyl-3,4-epoxy-2-methylbutan-2-ol 80

In the same way, the mesylate **79** (703.2 mg, 1.77 mmol) gave the *terminal epoxide* **80** (509.2 mg, 100%) as minute prisms, mp 112–114 °C (from EtOAc), $[\alpha]_D^{25}$ +2.2 (*c* 1.15 in $CHCl_3$) (Found: C, 67.3; H, 6.5; P, 10.3%; M − C_2H_3O, 259.0900. $C_{17}H_{19}O_3P$ requires C, 67.5; H, 6.33; P, 10.2%; *M* − C_2H_3O, 259.0888); R_F(EtOAc) 0.25; ν_{max}($CHCl_3$)/cm^{-1} 3440 (OH), 1440 (PPh) and 1150 (P=O); δ_H(250 MHz; $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 4.61 (1 H, s, OH), 2.94 (1 H, dd, *J* 4.0 and 2.8, $CH_{pro\text{-}R}H_{pro\text{-}S}O$), 2.77 [1 H, dd, *J* 5.2 and 2.8, *C*H(O)CH_2], 2.72 (1 H, dd, *J* 14.5 and 10.5, PCH_AH_B), 2.60 (1 H, dd, *J* 15.3 and 10.3, PCH_AH_B), 2.54 (1 H, dd, *J* 5.2 and 4.1, $CH_{pro\text{-}R}H_{pro\text{-}S}O$) and 1.24 (3 H, s, Me); δ_C(100 MHz; $CDCl_3$) 134–128 (Ph_2PO), 70.1$^-$ ($^2J_{PC}$ 4:4, COH), 58$^+$ [$^3J_{PC}$ 8.5, *C*H(O)CH_2], 44.2$^-$ (CH_2O), 38.5$^-$ ($^1J_{PC}$ 69.4, PCH_2) and 25.7$^+$ ($^3J_{PC}$ 5.8, Me); *m/z* 284 (19%, M − H_2O), 259 (87, M − C_2H_3O), 216 (18, Ph_2POMe), 215 (49, Ph_2POCH_2), 202 (49, Ph_2POH) and 201 (100, Ph_2PO). The ^{1}H NMR spectrum of this material in the presence of 1-(9-anthryl)-2,2,2-trifluoroethanol[24] showed an enantiomeric excess of 73%.

(2*S*,3*S*)-1-Diphenylphosphinoyl-3,4-epoxybutan-1-ol 84

In the same way, the mesylate **83** (120.6 mg, 0.314 mmol) gave the *terminal epoxide* **84** (72.2 mg, 80%) as prisms, mp 121–123 °C (from EtOAc), $[\alpha]_D^{25}$ +17.3 (*c* 1.31 in $CHCl_3$) (Found: C, 66.5; H, 6.0; P, 10.8%; M − OH, 271.0875. $C_{16}H_{17}O_3P$ requires C, 66.66; H, 5.94; P, 10.74%; *M* − OH, 271.0888); R_F(EtOAc–10% MeOH) 0.41; ν_{max}($CHCl_3$)/cm^{-1} 3360 (OH), 1440 (PPh) and 1150 (P=O); δ_H(250 MHz; $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 4.6 (1 H, br s, OH), 3.83 (1 H, dq, *J* 10.0 and 6.0, C*H*OH), 3.03 (1 H, ddd, *J* 6.1, 3.8 and 2.6, CHOHC*H*O), 2.78 (1 H, dd, *J* 4.8 and 4.0, $CH_{pro\text{-}R}H_{pro\text{-}S}O$), 2.70 (1 H, dd, *J* 4.9 and 2.5, $CH_{pro\text{-}R}H_{pro\text{-}S}O$) and 2.60 (2 H, dd, *J* 10.1 and 6.3, PCH_2; δ_C(100 MHz; $CDCl_3$) 134–128 (Ph_2PO), 67.6$^+$ (CHOH), 54.6$^+$ ($^3J_{PC}$ 14.4, CHOH*C*HO), 46.2$^-$ (CH_2O) and 33.6$^-$ ($^1J_{PC}$ 71.4, PCH_2); *m/z* 271 (4%), M − OH), 245 (72, M − C_2H_3O), 216 (25, Ph_2POMe), 215 (49, Ph_2POCH_2), 202 (72, Ph_2POH) and 201 (100, Ph_2PO). The ^{1}H NMR spectrum of this material in the presence of 1-(9-anthryl)-2,2,2-trifluoroethanol[24] showed an enantiomeric excess of 35%.

(2*S*,3*S*)-4-Diphenylphosphinoyl-1-phenylsulfanylbutane-2,3-diol 85

Sodium benzenethiolate (41 mg, 0.31 mmol, 1.5 equiv.) was added to a stirred solution of the epoxy alcohol **84** (59.8 mg, 0.21 mmol) in dry ethanol (2 cm^3). After 1 h, the mixture was evaporated under reduced pressure and the residue dissolved in ethyl acetate. The solution was washed with dilute ammonia and water, dried (Na_2SO_4) and evaporated under reduced pressure. Purification of the residue by flash chromatography, eluting with EtOAc–2% MeOH, gave the *sulfide* **85** (67.7 mg, 82%) as an oil, $[\alpha]_D^{25}$ −1.7 (*c* 1.06 in $CHCl_3$; 35% ee); R_F(EtOAc–4% MeOH) 0.48; ν_{max}($CHCl_3$)/cm^{-1} 3380 (OH), 1440 (PPh) and 1150 (P=O); δ_H(250 MHz; $CDCl_3$) 7.8–7.1 (15 H, m, Ph_2PO and PhS), 4.00 (1 H, fine m), 3.65 (1 H, fine m) (C*H*OH × 2), 3.34 (1 H, dd, *J* 13.6 and 2, CH_AH_BS), 2.92 (1 H, dd, *J* 13.7 and 8.2, CH_AH_BS), 2.70 (1 H, m, PCH_AH_B) and 2.50 (1 H, m, PCH_AH_B); δ_C(100 MHz; $CDCl_3$) 135–126 (Ph_2PO and PhS), 72.6$^+$ ($^3J_{PC}$ 12.2, *C*HOHCH$_2$S), 69.7$^+$ ·($^2J_{PC}$ 4.8, PCH_2*C*HOH), 37.6$^-$ (CH_2S) and 32.1 ($^1J_{PC}$ 71.5, PCH_2).

(2*R*,3*R*)-1-Diphenylphosphinoyl-2-methyl-4-phenylsulfanylbutane-2,3-diol 86

In the same way, the epoxy alcohol **80** (155.2 mg, 0.514 mmol) gave, without further purification, the *sulfide* **86** (203.2 mg, 96%) as minute needles, mp 102.5–105 °C (from EtOAc), $[\alpha]_D^{25}$ −27.0 (*c* 0.81 in $CHCl_3$; >95% ee) (Found: C, 67.1; H, 6.2; P, 7.4%; M − H_2O, 394.1148. $C_{23}H_{25}O_3PS$ requires C, 66.97; H, 6.11; P, 7.51%; *M* − H_2O, 394.1156); R_F(EtOAc) 0.50; ν_{max}($CHCl_3$)/cm^{-1} 3500–3100 (OH), 1440 (PPh) and 1145 (P=O); δ_H(400 MHz, $CDCl_3$) 7.8–7.1 (15 H, m, Ph_2PO and PhS), 4.6 (1 H, br s, OH), 3.9 (1 H, br s, OH), 3.60 (1 H, dd, *J* 9.8 and 2.4, C*H*OH), 3.26 (1 H, dd, *J* 13.4 and 2.6, CH_AH_BS), 2.94 (1 H, dd, *J* 13.4 and 9.8, CH_AH_BS), 2.67 (2 H, ABP m, PCH_2) and 1.21 (3 H, s, Me); δ_C(100 MHz, CD_3OD) 136–128 (Ph_2PO and PhS), 75.7$^+$ ($^3J_{PC}$ 7.4, CHOH), 74.8$^-$ ($^2J_{PC}$ 4.7, HO*C*Me), 37.2$^-$ ($^1J_{PC}$ 69.1, PCH_2), 36.2$^-$ (CH_2S) and 26.1$^+$ ($^3J_{PC}$ 4.1, Me); *m/z* 394 (4%, M − H_2O), 303 (3, M − SPh), 285 (92, M − H_2O − SPh), 259 [56, Ph_2POCH_2C(OH)Me], 216 (27, Ph_2POMe), 215 (47, Ph_2POCH_2), 202 (51, Ph_2POH) and 201 (100, Ph_2PO).

(2*RS*,3*RS*)-1-Diphenylphosphinoyl-4-(4-hydroxyphenylsulfanyl)-2-methylbutane-2,3-diol 87

Butyllithium (1.5 mol dm^{-3} solution in hexane; 0.18 cm^3, 0.23 mmol, 1.0 equiv.) was added to a stirred solution of 4-hydroxybenzenethiol (86 mg, 0.681 mmol, 2.9 equiv.) in dry THF (2 cm^3) at 0 °C under nitrogen. The epoxy alcohol **80** (70.11 mg, 0.232 mmol) was added at 0 °C to the reaction mixture which was then allowed to warm to room temperature over 30 min. After this it was evaporated under reduced pressure, and the residue purified by flash chromatography, eluting with EtOAc, to yield the *sulfide* **87** (74.7 mg, 75%) as a foam (Found: M − 2 H_2O − HOC_6H_4S, 268.1014. $C_{23}H_{26}O_4PS$ requires *M* − $C_6H_9O_3S$, 268.1017); R_F(EtOAc) 0.36; ν_{max}($CHCl_3$)/cm^{-1} 3500–3100 (OH), 1440 (PPh) and 1145 (P=O); δ_H(250 MHz; CD_3OD) 7.8–7.4 (10 H, m, Ph_2PO), 7.28 (2 H, d, *J* 8.6, $C_6H_2H_2$), 6.71 (2 H, d, *J* 8.5, $C_6H_2H_2$), 3.44 (1 H, dd, *J* 9.9 and 2.1, C*H*OH), 3.16 (1 H, dd, *J* 13.5 and 2.1, CH_AH_BS), 2.85–2.65 (3 H, m, CH_AH_BS and PCH_2) and 1.15 (3 H, s, Me); δ_C(100 MHz, CD_3OD–$CDCl_3$) 134–116 (Ph_2PO and PhS), 74.9$^+$ (CHOH), 74.4$^-$ (4.7, HOCMe), 38.8$^-$ (CH_2S), 37.4$^-$ ($^1J_{PC}$ 69.3, PCH_2) and 25.3$^+$ ($^3J_{PC}$ 4.1, Me); *m/z* 268 (0.4%, M − 2 H_2O − HOC_6H_4S), 216 (30, Ph_2POMe), 215 (100, Ph_2POCH_2), 202 (10, Ph_2POH) and 201 (78, Ph_2PO).

(2*RS*,3*RS*)-1-Diphenylphosphinoyl-2-methyl-4-(3-phenylpropylsulfanyl)butane-2,3-diol 88

In the same way, the epoxy alcohol **80** (87.35 mg, 0.289 mmol) with 3-phenylpropanethiol (0.225 cm^3, 1.5 mmol, 5.2 equiv.) gave, after purification by flash chromatography, eluting with EtOAc–hexane (1 : 1) and then EtOAc, the *sulfide* **88** (106.0 mg, 81%) as an unrecrystallisable solid (Found: M − H_2O, 436.1649. $C_{26}H_{31}O_3PS$ requires *M* − H_2O, 436.1626; R_F-(EtOAc) 0.50; ν_{max}($CHCl_3$)/cm^{-1} 3300 (OH), 1440 (PPh) and 1160 (P=O); δ_H(400 MHz, $CDCl_3$) 7.9–7.1 (15 H, m, Ph_2PO and Ph), 4.62 (1 H, s, MeCO*H*), 3.84 (1 H, d, *J* 4.1, CHO*H*), 3.58 (1 H, dt, *J* 10.0 and 3.5, C*H*OH), 2.80 (1 H, dd, PCH_AH_B), 2.7 (4 H, m, CHOHCH_2S and CH_2CH_2S or CH_2Ph), 2.54 (1 H, dd, *J* 13.5 and 9.9, PCH_ACH_B), 2.51 (2 H, m, CH_2CH_2S or CH_2Ph), 1.87 (2 H, quintet, *J* 7.4, $CH_2CH_2CH_2$) and 1.21 (3 H, s, Me); δ_C(100 MHz, CD_3OD) 141–126 (Ph_2PO and PhS), 75.8$^+$ ($^3J_{PC}$ 7.2, CHOH), 74.8$^-$ ($^2J_{PC}$ 4.6, HO*C*Me), 37.2$^-$ ($^1J_{PC}$ 69.1, PCH_2), 34.7$^-$, 34.1$^-$, 31.6$^-$, 31.1$^-$ [$CH_2S(CH_2)_3$] and 25.9$^+$ ($^3J_{PC}$ 4.6, Me); *m/z* 436 (2%, M − H_2O), 259 [28, Ph_2POCH_2-

C(OH)Me], 216 (47, Ph_2POMe), 215 (87, Ph_2POCH_2), 202 (36, Ph_2POH) and 201 (100, Ph_2PO).

(2*SR*,3*RS*)-1-Azido-4-diphenylphosphinoyl-3-methylbutane-2,3-diol 89

A solution of sodium azide (35.5 mg, 0.55 mmol, 5 equiv.) and ammonium chloride (25.25 mg, 0.47 mmol, 4.25 equiv.) in water (0.125 cm^3) was added at room temperature to a solution of the epoxy alcohol **80** (33.5 mg, 0.111 mmol) in 2-methoxyethanol (1 cm^3). The mixture was refluxed (135 °C) for 45 min, cooled, and concentrated under reduced pressure. The residue was purified by flash chromatography, eluting with EtOAc, to give the *azide* **89** (37.1 mg, 97%) as minute prisms, mp 140–142 °C (from EtOAc) (Found: C, 59.3; H, 5.65; N, 11.0; P, 9.02%; M − CH_2N_3, 289.0972. $C_{17}H_{20}N_3O_3P$ requires C, 59.1; H, 5.8; N, 12.2; P, 9.0%; *M* − CH_2N_3, 289.0994); R_F(EtOAc) 0.45; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3100 (OH), 2100 (N_3), 1440 (PPh) and 1135 (P=O); δ_H(250 MHz, $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 4.5 (2 H, br s, OH × 2), 3.73 (1 H, m, C*H*OH), 3.37 (1 H, dd, *J* 12.7 and 7.9, $CH_AH_BN_3$), 3.29 (1 H, dd, *J* 12.7 and 3.8, $CH_AH_BN_3$), 2.67 (2 H, d, *J* 11.1, PCH_2) and 1.15 (3 H, s, Me); δ_C(100 MHz, $CDCl_3$) 134–128 (Ph_2PO), 76.4$^+$ ($^3J_{PC}$ 5.9, CHOH), 74.3$^-$ ($^2J_{PC}$ 4.5, CMe), 52.0$^-$ (CH_2N_3), 39.6$^-$ ($^1J_{PC}$ 68.0, PCH_2) and 25.8$^+$ (C*Me*); *m/z* 289 (1%, M − CH_2N_3), 259 [25, $Ph_2POCH_2C(OH)Me$], 215 (9, Ph_2POCH_2), 202 (30, Ph_2POH), 201 (70, Ph_2PO) and 85 (100).

(2*SR*,3*RS*)-4-Diphenylphosphinoyl-3-methyl-1-(4-methylphenylsulfonamido)butane-2,3-diol 90

5% Palladium-on-charcoal (45 mg, 25 mol%) was added to a solution of the azide **89** (117.78 mg, 0.34 mmol) in dry methanol (2 cm^3). The resulting suspension was stirred under an atmosphere of hydrogen for 23 h, filtered through Celite and evaporated under reduced pressure to give the amine **92** (97 mg, 90%). DMAP (43 mg, 0.35 mmol, 1.15 equiv.) and toluenesulfonyl chloride (58 mg, 0.30 mmol, 1.0 equiv.) were added to a solution of this material in dry dichloromethane (1 cm^3). After 18 h, the reaction mixture was concentrated and purified by flash chromatography, eluting with EtOAc–hexane (4:1) and then EtOAc–10% hexane, to give the *sulfonamide* **90** (79.5 mg, 49%) as minute needles, mp 175–177 °C (from EtOAc–MeOH) (Found: C, 60.9; H, 5.9; N, 3.0; P, 6.44%; M − $TsNHCH_2CHOH$, 259.0907. $C_{24}H_{28}NO_5PS$ requires C, 60.88; H, 5.96; N, 2.96; P, 6.54%; *M* − $TsNHCH_2CHOH$, 259.0888); R_F(EtOAc) 0.34; δ_H(250 MHz, $CDCl_3$) 7.8–7.2 (14 H, m, Ph_2PO and $MeC_6H_4SO_2$), 5.38 (1 H, d, *J* 6.5, NH), 4.7 (1 H, s, OH), 4.3 (1 H, s, OH), 3.61 (1 H, m, C*H*OH), 3.20 (1 H, ddd, *J* 12.3, 9.1 and 3.4, CH_AH_BN), 2.85 (1 H, ddd, *J* 12.2, 8.3 and 2.6, CH_AH_BN), 2.63 (2 H, ABP m, PCH_2), 2.38 (3 H, s, C_6H_4Me) and 1.15 (3 H, s, C*Me*); δ_C(100 MHz, $CDCl_3$) 144–127 (Ph_2PO and $MeC_6H_4SO_2$), 75.1$^+$ ($^3J_{PC}$ 6.5, CHOH), 74.4$^-$ ($^2J_{PC}$ 4.4, HOCMe), 44.0$^-$ (CH_2NH), 38.4$^-$ ($^1J_{PC}$ 68.4, PCH_2), 25.5$^+$ ($^3J_{PC}$ 4.6, HOC*Me*) and 21.5$^+$ (*Me*C_6H_4); *m/z* 259 [8%, $Ph_2POCH_2C(OH)Me$], 216 (36, Ph_2POMe), 215 (90, Ph_2POCH_2), 202 (17, Ph_2POH), 201 (80, Ph_2PO) and 91 (100, MeC_6H_4).

(2*SR*,3*RS*)-1-Acetamido-4-diphenylphosphinoyl-3-methylbutane-2,3-diol 91

5% Palladium-on-charcoal (90 mg, 25 mol%) was added to a solution of the azide **89** (58.9 mg, 0.17 mmol) in dry methanol (3.5 cm^3). The resulting suspension was stirred under an atmosphere of hydrogen for 23 h, filtered through Celite and evaporated under reduced pressure to give the amine **92** (50.9 mg, 94%). Dry dichloromethane (1 cm^3) and acetic anhydride (0.5 cm^3) were added to the mixture which was then stirred at room temperature under nitrogen for 20 min. After this it was concentrated and the residue purified by flash chromatography to yield the *acetamide* **91** (40.1 mg, 74%) as a foam (Found: M − H_2O, 343.1343. $C_{19}H_{24}NO_4P$ requires *M* − H_2O, 343.1338); R_F(EtOAc–20% MeOH) 0.28; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3100 (OH and NH), 1660 (C=O), 1440 (PPh) and 1150 (P=O); δ_H(250 MHz, $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 6.63 (1 H, br m, NH), 4.6 (2 H, br s, OH × 2), 3.60 (2 H, m, C*H*OH and CH_AH_BN), 3.04 (1 H, ddd, *J* 13.6, 7.9 and 4.4, CH_AH_BN), 2.66 (2 H, ABP m, PCH_2), 1.90 (3 H, s, O=CMe) and 1.14 (3 H, s, HOC*Me*); δ_C(100 MHz, $CDCl_3$) 134–128 (Ph_2PO), 76.2$^+$ ($^3J_{PC}$ 6.6, CHOH), 74.3$^-$ ($^2J_{PC}$ 4.6, HO*C*Me), 40.8$^-$ (CH_2NH), 37.9$^-$ ($^1J_{PC}$ 68.6, PCH_2), 25.4$^+$ ($^3J_{PC}$ 5.1, HOC*Me*) and 23.1$^+$ (*Me*C=O); *m/z* 343 (2%, M − H_2O), 259 (100, Ph_2POCH_2COHMe), 216 (22, Ph_2POMe), 215 (49, Ph_2POCH_2), 202 (71, Ph_2POH) and 201 (88, Ph_2PO).

(2*SR*,3*RS*)-1-Amino-4-diphenylphosphinoyl-3-methylbutane-2,3-diol 92

Concentrated ammonia (*d* 0.880; 1 cm^3) was added to a stirred solution of the epoxy alcohol **80** (73.1 mg, 0.242 mmol) in methanol (1 cm^3). After 51 h, the mixture was evaporated under reduced pressure to give the amine **92** (77.6 mg, 100%) as an oil; δ_H(250 MHz, $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 4.0 (4 H, br s, OH × 2 and NH_2), 3.49 (1 H, dd, *J* 3.8 and 7.0, C*H*OH), 3.0–2.7 (4 H, m, PCH_2 and NH_2) and 1.06 (3 H, s, Me).

The amine **92** was characterised by conversion into the acetamide **91**: acetic anhydride (1 cm^3) was added to a solution of the amine **92** (77.6 cm^3, 0.24 mmol) in dichloromethane (2 cm^3). After 1 h, the reaction mixture was concentrated under reduced pressure and purified by flash chromatography, eluting with EtOAc–16% MeOH, to yield the acetamide **91** (70.6 mg, 81%).

(2*SR*,3*RS*)-1-(5-Bromouracil-1-yl)-4-diphenylphosphinoyl-3-methylbutane-2,3-diol 93

Sodium hydride (60% suspension; 9.4 mg, 0.24 mmol, 1.1 equiv.) was added to a stirred solution of 5-bromouracil (104.3 mg, 0.545 mmol, 2.5 equiv.) in dry DMF (1.5 cm^3) at room temperature under nitrogen. After 30 min, evolution of hydrogen had ceased, and the epoxy alcohol **80** (67.0 mg, 0.222 mmol) was added to the solution. The mixture was stirred at 70 °C for 4 h, cooled to room temperature, diluted with ethyl acetate (25 cm^3) and washed with dilute aqueous sodium hydroxide (10 cm^3) and water. The aqueous fractions were acidified with dilute hydrochloric acid (12 cm^3) and extracted with ethyl actetate (10 cm^3 × 2). The combined organic fractions were washed with water (10 cm^3 × 2), dried (Na_2SO_4) and evaporateed under reduced pressure to yield a crude oil. Purification of this by flash chromatography, eluting with EtOAc and then EtOAc–5% MeOH, gave the *pyrimidine* **93** (60.0 mg, 59%) as a solid, mp > 220 °C (decomp.). (Found: M − CH_2pyrimidine − H_2O, 271.0895. $C_{21}H_{25}BrO_5P$ requires *M* − $C_5H_9N_2O_3Br$, 271.0888); R_F(EtOAc) 0.18; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3100 (OH), 1440 (PPh) and 1150 (P=O); δ_H(250 MHz, $CDCl_3$) 10.72 (1 H, br s, NH), 7.94 (1 H, s, C^6H), 7.8–7.4 (10 H, m, Ph_2PO), 5.8 (1 H, br s, OH), 4.6 (1 H, br s, OH), 4.25 (1 H, d, *J* 13.0, CH_AH_BN), 3.84 (1 H, d, *J* 9.6, C*H*OH), 3.41 (1 H, dd, *J* 13.0 and 10.1, CH_AH_BN), 2.77 (2 H, ABP m, PCH_2) and 1.14 (3 H, s, Me); δ_C(100 MHz, CD_3OD) 160.2, 150.7, 146.0, 133–128 (Ph_2PO), 95.4, 74.4$^+$ (CHOH), 74.4$^-$ (HO*C*Me), 50.3$^-$ (CH_2N), 38.7$^-$ ($^1J_{PC}$ 67.9, PCH_2) and 25.6$^+$ (Me); *m/z* 271 (9%, M − H_2O − CH_2pyrimidine), 259 [14, $Ph_2POCH_2C(OH)Me$], 216 (19, Ph_2POMe), 215 (79, Ph_2POCH_2), 202 (40, Ph_2POH) and 201 (100, Ph_2PO).

(2*SR*,3*RS*)-1-(6-Chloropurin-9-yl)-4-diphenylphosphinoyl-3-methylbutane-2,3-diol 94

Sodium hydride (60%; 15.7 mg, 0.393 mmol, 1.0 equiv.) was added to a stirred solution of 6-chloropurine (122.7 mg, 0.794

mmol, 2.02 equiv.) in dry DMF (2 cm^3) at room temperature under nitrogen. After 25 min, evolution of hydrogen had ceased, and the epoxy alcohol **80** (118.6 mg, 0.393 mmol) was added to the blue–brown solution. The mixture was stirred at 70 °C for 11 h, during which time it became purple. After cooling to room temperature, the mixture was diluted with ethyl acetate (40 cm^3) and washed with dilute aqueous ammonia (10 cm^3). The aqueous layer was extracted with ethyl acetate (10 cm^3) and the combined organic fractions were dried (Na_2SO_4) and evaporated under reduced pressure to yield a crude oil. Purification of this by flash chromatography, eluting with EtOAc–6% MeOH and then EtOAc–10% MeOH, gave the *purine* **94** (84.5 mg, 47%) as minute needles, mp 117–124 °C (from EtOAc) [Found: C, 57.5; H, 4.7; N, 12.2; P, 7.5%; M − H_2O, 438.1016. $C_{22}H_{22}ClN_4O_3P$ requires C, 57.8; H, 4.85; N, 12.26; P, 6.78%; M − H_2O, 438.1007 (^{35}Cl)]; R_F(EtOAc–6% MeOH) 0.31; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3150 (OH), 1440 (PPh) and 1145 (P=O); δ_H(400 MHz, $CDCl_3$) 8.69 (1 H, s, C^2H), 8.24 (1 H, s, C^8H), 7.8–7.4 (10 H, m, Ph_2PO), 5.24 (1 H, d, *J* 5.3, CHO*H*), 4.62 (1 H, dd, *J* 14.0 and 2.3, CH_AH_BN), 4.29 (1 H, s, $NCH_2CO H$), 4.14 (1 H, dd, *J* 14.0 and 9.6, CH_AH_BN), 3.91 (1 H, m, C*H*OH), 2.76 (1 H, dd, *J* 15.3 and 9.9, PCH_AH_B), 2.68 (1 H, dd, *J* 15.3 and 12.4, PCH_AH_B) and 1.32 (3 H, s, Me); δ_C(100 MHz, $CDCl_3$–CD_3OD) 151.8, 151.5, 150.6, 147.1, 133–128 (Ph_2PO), 75.2$^+$ (CHOH), 74.0$^-$ (HO*C*Me), 45.4$^-$ (CH_2N), 37.8$^-$ ($^1J_{PC}$ 68.2, PCH_2) and 25.6$^+$ (Me); *m*/*z* 440 [0.5%, M − H_2O (^{37}Cl)], 438 [0.6, M − H_2O (^{35}Cl)], 271 (31, M − H_2O − CH_2purine), 259 [41, $Ph_2POCH_2C(OH)Me$], 215 (45, Ph_2POCH_2), 202 (53, Ph_2POH) and 201 (100, Ph_2PO).

Also obtained was (2SR,3RS)-1-(6-*chloropurin*-1-*yl*)-4-*diphenylphosphinoyl*-3-*methylbutane*-2,3-*diol* **95** (22.1 mg, 12%) as an oil (Found: M − CH_2purine, 289.0986. $C_{22}H_{22}ClN_4O_3P$ requires M − CH_2purine, 289.0994); R_F(EtOAc–6% MeOH) 0.16; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3150 (OH), 1440 (PPh) and 1145 (P=O); δ_H(400 MHz, $CDCl_3$) 8.68 (1 H, s, C^2H), 8.25 (1 H, s, C^8H), 7.8–7.4 (10 H, m, Ph_2PO), 4.89 (1 H, dd, *J* 14.3 and 2.1, CH_AH_BN), 4.22 (1 H, dd, *J* 14.4 and 9.9, CH_AH_BN), 3.99 (1 H, dd, *J* 10.0 and 2.1, C*H*OH), 2.82 (1 H, d, *J* 12.0, PCH_2) and 1.30 (3 H, s, Me); δ_C(100 MHz, $CDCl_3$–CD_3OD) 161.3, 151.9, 151.0, 142.7, 133–128 (Ph_2PO), 75.4$^+$ ($^3J_{PC}$ 5.3, CHOH), 74.3$^-$ ($^2J_{PC}$ 4.0, HO*C*Me), 48.4$^-$ (CH_2N), 38.7$^-$ ($^1J_{PC}$ 67.2, PCH_2) and 26.2$^+$ ($^3J_{PC}$ 4.2, Me); *m*/*z* 289 (5, M − CH_2purine), 271 (4, M − H_2O − CH_2purine), 259 [12, $Ph_2POCH_2C(OH)Me$], 215 (75, Ph_2POCH_2), 202 (22, Ph_2POH) and 201 (100, Ph_2PO).

(3*SR*,4*RS*)-5-Diphenylphosphinoyl-3,4-dihydroxy-4-methylpentanenitrile 96

Anhydrous ytterbium(III) chloride (208.9 mg, 0.748 mmol, 1.15 equiv.), which had been dried for 4 h at 200 °C under reduced pressure, was dissolved in dry THF (30 cm^3) by sonication for 30 min, after which the solution was cooled to −70 °C under nitrogen. Butyllithium (1.6 mol dm^{-3} solution in hexane; 1.4 cm^3, 2.25 mmol, 3.5 equiv.) was added to the mixture and stirring was continued at −70 °C for 15 min. During this time the solution became brown and then yellow. The reaction mixture was warmed to 0 °C, and trimethylsilyl cyanide (0.8 cm^3, 6.0 mmol, 9 equiv.) was added to it. After a further 15 min at 0 °C, a solution of the epoxy alcohol **80** (195.6 mg, 0.648 mmol) in THF (2 cm^3) was added to the red–brown solution. The reaction mixture was warmed to room temperature overnight, during which time the colour faded considerably. After 16 h, dilute hydrochloric acid (10 cm^3) was added to the mixture which was then stirred for 1 h. After this, the mixture was neutralised with saturated aqueous sodium carbonate, diluted with brine (50 cm^3) and concentrated under reduced pressure to remove the THF. The aqueous suspension was extracted with ethyl acetate (3 × 50 cm^3) and the combined extracts were dried (Na_2SO_4) and evaporated under reduced pressure. The residue was purified by flash chromatography, eluting with EtOAc–hexane (4:1) to give the *nitrile* **96** (195.4 mg, 92%) as minute needles, mp 131–132.5 °C (from EtOAc–MeOH) (Found: C, 65.4; H, 6.0; N, 4.3; P, 9.3%; *M* − H_2O, 311.1091. $C_{18}H_{20}NO_3P$ requires C, 65.65; H, 6.12; N, 4.25; P, 9.41%; *M* − H_2O, 311.1075); R_F(EtOAc) 0.34; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3100 (OH), 2260 (CN), 1440 (PPh) and 1145 (P=O); δ_H(400 MHz, $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 5.15 (1 H, br s, OH), 4.5 (1 H, br s, OH), 3.88 (1 H, m, C*H*OH), 2.69 (2 H, ABP m, PCH_2), 2.59 (1 H, dd, *J* 16.7 and 4.2, CH_AH_BCN), 2.52 (1 H, dd, *J* 16.7 and 8.5, CH_AH_BCN) and 1.10 (3 H, s, Me); δ_C(100 MHz, $CDCl_3$) 134–128 (Ph_2PO), 118.6$^-$ (CN), 74.3$^-$ ($^2J_{PC}$ 4.1, HO*C*Me), 73.3$^+$ ($^3J_{PC}$ 6.2, CHOH), 37.8$^-$ ($^1J_{PC}$ 66.1, PCH_2), 25.8$^+$ ($^3J_{PC}$ 4.5, Me) and 20.4$^+$ (*C*H_2CN); *m*/*z* 311 (4%, M − H_2O), 259 [80%, $Ph_2POCH_2C(OH)Me$], 216 (17, Ph_2POMe), 215 (48, Ph_2POCH_2), 202 (87, Ph_2POH) and 201 (100, Ph_2PO).

(2*RS*,3*SR*)-5-Acetamido-1-diphenylphosphinoyl-2-methylpentane-2,3-diol 97

Platinum dioxide (10 mg, 0.044 mmol, 38 mol%) was added to a solution of the nitrile **96** (38.5 mg, 0.117 mmol) in acetic anhydride (2 cm^3). The suspension was stirred under an atmosphere of hydrogen for 7 h, filtered through Celite, evaporated under reduced pressure and the residue purified by PLC, eluting with EtOAc–12% MeOH, to give the *acetamide* **97** (16.4 mg, 37%) as an oil (Found: M − H_2O_2, 341.1566. $C_{20}H_{26}NO_4P$ requires *M* − H_2O_2, 341.1545); R_F(EtOAc–10% MeOH) 0.10; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600–3100 (OH), 1660 (amide), 1440 (PPh) and 1150 (P=O); δ_H(400 MHz, $CDCl_3$) 7.8–7.4 (10 H, m, Ph_2PO), 6.48 (1 H, br m, NH), 3.60 (1 H, m, C*H*OH), 3.53 (1 H, m, CH_AH_BN), 2.99 (1 H, m, CH_AH_BN), 2.66 (1 H, dd, *J* 15.3 and 10.0, PCH_AH_B), 2.57 (1 H, dd, *J* 15.2 and 11.7, PCH_AH_B), 1.93 (3 H, s, O=CMe), 1.67 (1 H, m, $CHOHCH_AH_B$), 1.45 (1 H, m, $CHOHCH_AH_B$) and 1.16 (3 H, s, HOC*Me*); δ_C(100 MHz, $CDCl_3$) 133–128 (Ph_2PO), 75.6$^+$ ($^3J_{PC}$ 6.7, CHOH), 75.0$^-$ ($^2J_{PC}$ 5.1, HO*C*Me), 38.2$^-$ ($^1J_{PC}$ 68.8, PCH_2), 37.3$^-$ (CH_2NH), 29.9$^-$ (CHOH*C*H_2), 25.1$^+$ ($^3J_{PC}$ 6.9, HOC*Me*) and 23.3$^+$ (*Me*C=O); *m*/*z* 341 (9%, M − H_2O_2), 216 (38, Ph_2POMe), 215 (100, Ph_2POCH_2), 202 (24, Ph_2POH) and 201 (72, Ph_2PO).

In another experiment, the nitrile **96** (28.0 mg) and 5% palladium-on-charcoal (90 mg, 50 mol%) in acetic anhydride (1.7 cm^3) gave, after 24 h, and without purification, the ketone[35] **98** (14.6 mg, 67%); δ_H(250 MHz; $CDCl_3$), 7.8–7.4 (10 H, m, Ph_2PO), 3.59 (2 H, d, *J* 14.8) and 2.30 (3 H, s, Me).

(*R*)-1-Phenylsulfanylbut-3-en-2-ol 99

Sodium hydride (60% suspension; 20 mg, 0.50 mmol, 5 equiv.) was added to a stirred solution of the sulfide **85** (37.3 mg, 0.094 mmol) in dry DMF under nitrogen. The mixture was heated to 60 °C for 30 min, cooled, quenched with saturated aqueous ammonium chloride (1 cm^3), and partitioned between ether (20 cm^3) and water (20 cm^3). The aqueous layer was extracted into ether (×2), and the combined organic fractions were washed with water, dried (Na_2SO_4) and evaporated under reduced pressure. Purification of the residue by PLC, eluting with hexane–EtOAc (4:1), gave the *allylic alcohol* **99** (4.9 mg, 29%) as an oil, $[\alpha]_D^{25}$ −7.0 (*c* 0.23 in $CHCl_3$; 35% ee) (Found: M$^+$, 180.0600. $C_{10}H_{12}OS$ requires *M*, 180.0609); R_F[hexane–EtOAc (4:1)] 0.35; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600 (OH) and 1600 (Ph); δ_H(400 MHz; $CDCl_3$) 7.4–7.1 (5 H, m, PhS), 5.87 (1 H, ddd, *J* 16.7, 10.4, 6.0, C*H*=CH_2), 5.31 (1 H, d, *J* 17.2, CH=CH_AH_B), 5.18 (1 H, d, *J* 10.4, CH=CH_AH_B), 4.18 (1 H, m, C*H*OH), 3.16 (1 H, dd, *J* 13.6 and 4.0, CH_AH_BS) and 2.94 (1 H, dd, *J* 13.6 and 8.5, CH_AH_BS); *m*/*z* 180 (27%, M$^+$), 124 (42, PhSMe), 123 (100, $PhSCH_2$), 110 (24, PhSH) and 109 (13, PhS).

(*R*)-3-Methyl-1-phenylsulfanylbut-3-en-2-ol 100

In the same way, the sulfide **86** (250.3 mg, 0.61 mmol), with sodium hydride (60% suspension; 100 mg, 2.5 mmol, 4.1 equiv.) in dry DMF (10 cm^3) gave, after 90 min, a crude product. Purification of this by PLC, eluting with hexane–ether (4:1), gave the allylic alcohol **100** (17.3 mg, 15%) as an oil, $[\alpha]_D^{25}$ −45.7 (*c* 0.64 in $CHCl_3$; >95% ee) (Found: M, 194.0778. $C_{11}H_{14}OS$ requires *M*, 194.0765); R_F[EtOAc–hexane (4:1)] 0.27; $\nu_{max}(CHCl_3)/cm^{-1}$ 3600 (OH), 3080 (=CH–H) and 1650 (C=C); δ_H(250 MHz, $CDCl_3$) 7.5–7.1 (5 H, m, PhS), 5.03 (d, *J* 1, C=CH_AH_B), 4.91 (d, *J* 1, C=CH_AH_B), 4.12 (dd, *J* 8.9 and 3.6, C*H*OH), 3.20 (1 H, dd, *J* 13.5 and 3.5, CH_AH_BS), 2.97 (1 H, dd, *J* 13.5 and 9.4, CH_AH_BS), 2.5 (1 H, br s, OH) and 1.74 (3 H, d, *J* 1, Me); δ_C(100 MHz, CD_3OD) 148.5$^-$ (MeC=CH_2), 130–126 (PhS), 112.3$^-$ (C=CH_2), 73.8$^+$ (CHOH), 40.7$^-$ (CH_2S) and 21.1$^+$ (Me); *m/z* 194 (M^+, 28%), 124 (100, PhSMe), 123 (74, $PhSCH_2$), 110 (16, PhSH) and 109 (11, PhS).

Attempted Horner–Wittig elimination of acetamide 91

In the same way, the acetamide **91** (58.7 mg, 0.163 mmol), with sodium hydride (60% suspension; 38.1 g, 0.95 mmol, 5.8 equiv.) in dry THF (5 cm^3) gave, after refluxing for 20 min, a crude product. Purification by PLC, eluting with EtOAc–10% MeOH, gave methyldiphenylphosphine oxide (20.7 mg, 59%).

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