Control of remote stereochemistry using phosphine oxides: formal synthesis of any stereoisomer diol (*RR*, *RS*, *SR* or *SS*) bearing 1,5-related stereogenic centres across an *E* double bond

Adam Nelson *† and Stuart Warren

University Chemical Laboratory, Lensfield Road, Cambridge, UK CB2 1EW

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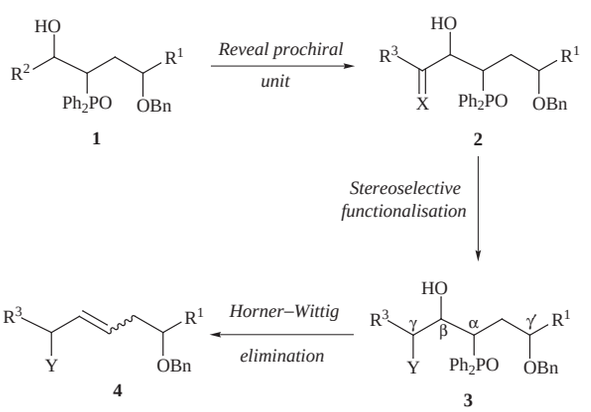
γ-Alkenyl β-hydroxy phosphine oxides have been epoxidised stereoselectively to give γ,δ-epoxy β-hydroxy phosphine oxides with high *anti* stereoselectivity. The γ-anisyl or γ-furyl ring of γ-aryl β-hydroxy phosphine oxides have been cleaved oxidatively to reveal a carboxylic acid and a ketone respectively. In the latter case, the ketone was reduced highly stereoselectively to give (4*R**,5*S**,6*R**)-8-benzyloxy-6-diphenylphosphinoyloctane-1,4,5-triol as a single diastereoisomer with three controlled stereogenic centres. This method was then applied to the synthesis of three of the diastereoisomers of 8-benzyloxy-6-diphenylphosphinoyldodecane-1,4,5-triol with four controlled stereogenic centres; the middle two stereogenic centres were removed using an *E*-selective Horner–Wittig elimination to give either diastereoisomer of 8-benzyloxydodec-5-ene-1,4-diol with 1,5-related stereogenic centres across an *E* alkene.

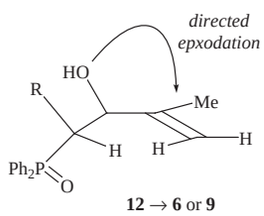
Introduction

In the preceding paper,[1] we outlined a general strategy for the synthesis of allylically functionalised compounds[2,3] with 1,4-related stereogenic centres across double bonds of fixed configuration.[4] In this paper, we take this strategy one stage further in the synthesis of alkenyl diols with 1,5-related stereogenic centres across an *E* double bond. We have shown that the diphenylphosphinoyl group[5] can be used to control the 1,3,4-related stereogenic centres in β-hydroxy phosphine oxides **1**.[1] We now describe methods which allow the R^2 group of phosphine oxides **1** to be transformed into a prochiral unit (as in **2**) which can be functionalised stereoselectivity (for example by alkene epoxidation, ketone reduction) to give phosphine oxides **3** with four stereogenic centres (Scheme 1). Horner–Wittig elimination will then be used to "harvest" the middle two stereogenic centres to give alkenes **4** with a controlled 1,5 chiral relationship. The aim of the work was to develop methods which allow the *general* synthesis of any stereoisomer of the β-hydroxy phosphine oxides **3** and hence the alkenes **4**.



Scheme 1

† Present address: School of Chemistry, University of Leeds, Leeds, UK LS2 9JT.



12 → **6** or **9**

Fig. 1

Results and discussion

Stereoselective epoxidation of γ,δ-unsaturated β-hydroxy phosphine oxides

Initially, we looked at epoxidation as a means of introducing a γ stereogenic centre into molecules of general structure **2** (X = CH_2). We chose to use racemic β-hydroxy phosphine oxides **5** and **8** as models of **2** (X = CH_2). Epoxidation of **5** and **8** with MCPBA gave the epoxides **6** and **9** with high diastereoselectivity and in excellent yield; in both cases, the epoxide oxygen of the products was on the opposite face to the hydroxy group as shown in Scheme 2. Earlier work suggested that the epoxides were formed by directed epoxidation of the conformation **12** in which 1,2-allylic strain is minimised (Fig. 1).[3] Epoxides similar to **6** and **9** are extremely sensitive to Payne rearrangement,[3,6] so the crude reaction mixtures were treated directly with lithium benzenethiolate,[7] in the presence of a PhSH buffer, to give the diols **7** and **10**. We also tried unsuccessfully to open the epoxide **6** with the anions of 5-bromouracil and 6-chloropurine.[8,9] Horner–Wittig elimination of the β-hydroxy phosphine oxide **10** gave the *Z*-allylic alcohol **11** in poor yield. ‡

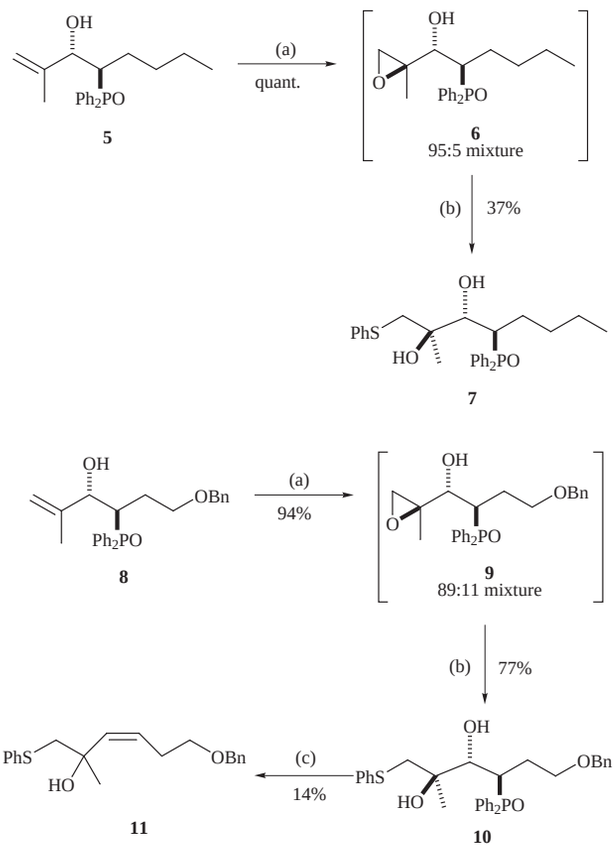
Many features of this epoxidation route were unsatisfactory. To start with, the syntheses of optically active allylic alcohols **1** (R^2 = alkenyl) were neither flexible nor stereoselective.[1] In any case, precedent suggested that epoxidation of the *syn* isomers of **6** and **9** would have been low yielding and unselective.[3] Furthermore, we had been unable to find conditions which

‡ In the light of previous work, these low-yielding eliminations were, perhaps, to be expected (ref. 8).

Table 1 Acylation and oxidative cleavage of the β-hydroxy phosphine oxides **16**, **20** and **24**

		Acylation			Oxidative cleavage			Transformation		
Entry	Starting material	Conditions[a]	β-acyloxy phosphine oxide	Yield (%)	Conditions[a]	Product	Yield (%)	Conditions[a]	Product	Yield (%)
1a	**16**	(a)	**17**	95	(b)	**18**	91	(c)	**19**	55
1b								(d)	**19**	44
2	**20**	(a)	**21**	81	(b)	**22**	[b]	(e)	**23**	18
3	**25**	(a)	**25**	>98	(b)	**26**	>98	—	—	—
4	**16**	(f)	**27**	72	(b)	**28**	[b]	(c)	**29**	59
5	**20**	(f)	**30**	75	(b)	**31**	[b]	(c)	**32**	55
6	—	—	**36**	—	(b)	**37**	[b]	(c)	**38**	61

[a] *Reagents and conditions*: (a) PhCOCl, cat. DMAP, Et_3N; (b) cat. $RuCl_3$, $NaIO_4$, CH_2Cl_2–MeCN–H_2O; (c) $SOCl_2$, MeOH; (d) CH_2N_2; (e) CDI, MeNHOMe·HCl, CH_2Cl_2; (f) Ac_2O, pyridine. [b] Crude product was the acid by 400 MHz ^1H NMR spectroscopy.



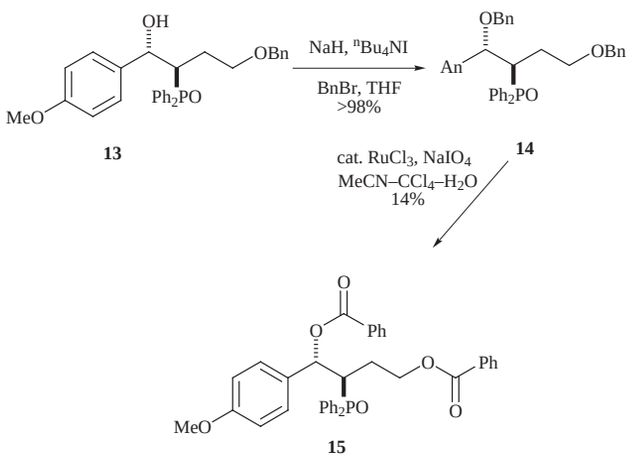
Scheme 2 *Reagents and conditions*: (a) *M*-CPBA, Na_2HPO_4, CH_2Cl_2, 0 °C; (b) PhSLi, PhSH, THF; (c) NaH, DMF.

promoted clean Horner–Wittig elimination of diols like **10**. These problems led us to abandon this strategy.

Oxidative cleavage of the anisyl ring of β-anisyl β-acyloxy phosphine oxides

An alternative strategy for the synthesis of molecules similar to **2** (X = O; R^3 = OH) involved the oxidative cleavage of the aromatic ring of phosphine oxides similar to **1** (R^2 = *p*-$MeOC_6H_4$). To start with, we chose to work with models of the phosphine oxides **1** (R^2 = *p*-$MeOC_6H_4$) such as **13**. The β-hydroxy phosphine oxide **13** was protected as the dibenzyl ether **14**; oxidation of the dibenzyl ether **14** under Sharpless's conditions[10] gave only diester **15** in low yield (Scheme 3). Evidently, the benzyl ethers of **14** are more susceptible to oxidation under these conditions than the anisyl ring.

We protected the β-hydroxy phosphine oxides **16**, **20** and **24** as benzoates **17**, **21** and **25** and acetates (*e.g.* **27** or **30**) because these functional groups were known to be stable to oxidation under Sharpless's conditions (Scheme 4; Table 1).[10] In a similar



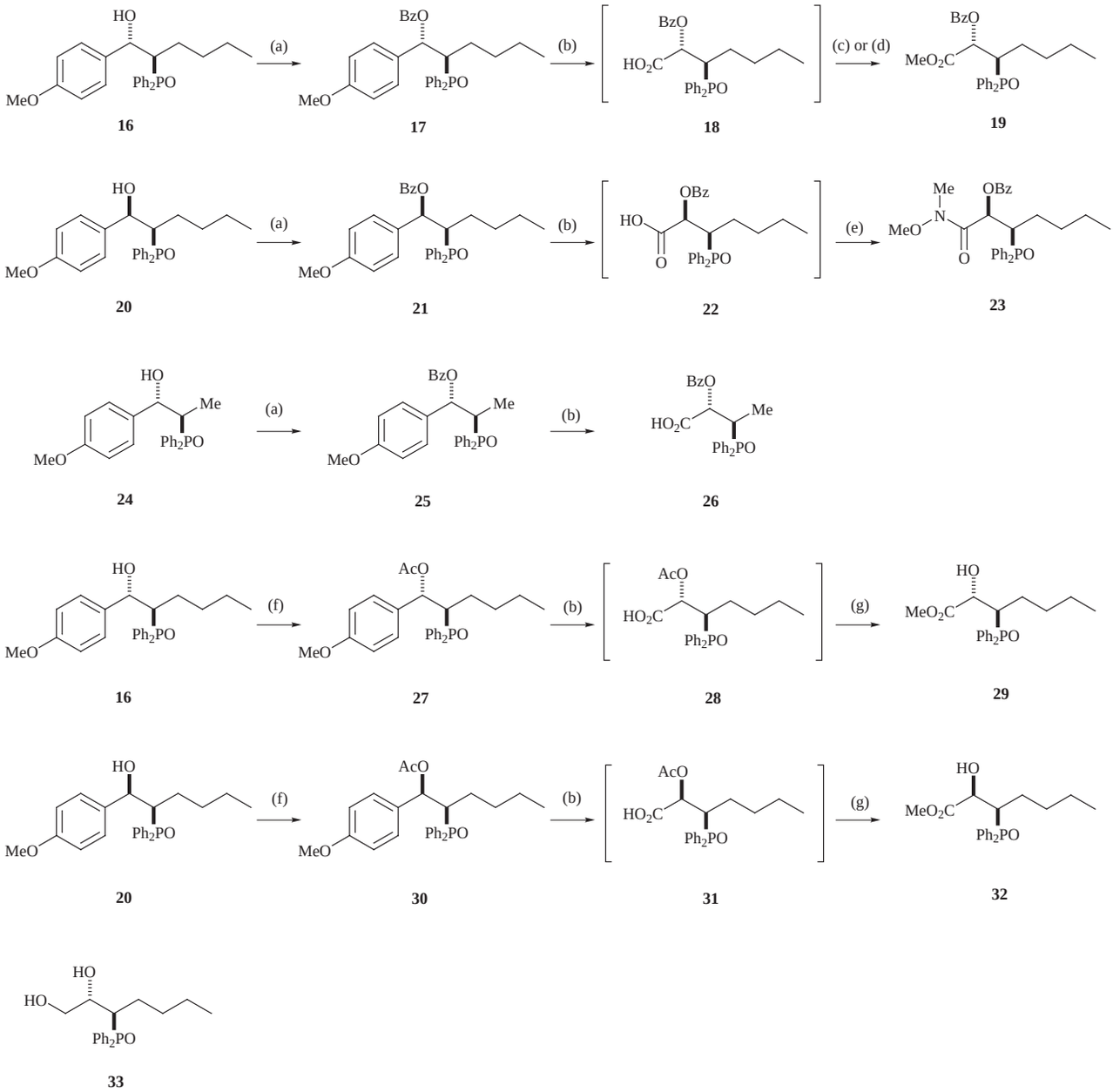
Scheme 3

vein, the β-hydroxy phosphine oxide **13** was converted into the phthalimide **36** using the chemistry described in Scheme 5; the benzyl ether of **34** was easily removed by hydrogenolysis and the alcohol of **35** was substituted by phthalimide, using a Mitsunobu reaction.[11]

The benzoates **17**, **21** and **25** and the acetates **27**, **30** and **36** were oxidised to the corresponding acids using sodium periodate and catalytic ruthenium trichloride in a 1:1:1 mixture of acetonitrile, water and carbon tetrachloride (Schemes 4 and 5; Table 1). Practically, we found that about 15 equivalents of sodium periodate were necessary for the reaction to reach completion; it was also necessary to use considerably more solvent[12] than that recommended by Sharpless[10] to allow efficient stirring of the reaction mixture. The crude reaction mixtures were analysed by ^1H NMR and were almost exclusively the required carboxylic acids. The efficiency and chemoselectivity of these oxidation reactions is remarkable; in each case, the anisyl ring is selectively oxidised in the presence of three phenyl rings, each of which is protected by a neighbouring carbonyl or phosphinoyl group.

Ideally, we wanted to develop simple and efficient ways to convert the crude acids into useful prochiral units. For example, the acid **18** was converted into the methyl ester **19** by treatment with acidic methanol solution (entry 1) or diazomethane (entry 2, Table 1); the methyl ester **19** was, however, resistant to attack by a variety of organometallic reagents and could be converted in only 52% yield into the diol **33** using lithium aluminium hydride. We have previously synthesised similar diphenylphosphinoyl diols using the Sharpless asymmetric dihydroxylation reaction.[13] The acid **22** was converted in low yield into the Weinreb amide **23** using carbonyl diimidazole and *N*,*O*-dimethylhydroxylamine hydrochloride.[14]

Most of the problems associated with protecting β-hydroxy phosphine oxides as benzoates were easily solved by using an acetate protecting group instead (entries 4–6, Table 1). The



Scheme 4 *Reagents and conditions*: (a) PhCOCl, cat. DMAP, Et_3N; (b) cat. $RuCl_3$, $NaIO_4$, CH_2Cl_2–MeCN–H_2O; (c) $SOCl_2$, MeOH; (d) CH_2N_2; (e) CDI, MeNHOMe·HCl, CH_2Cl_2; (f) Ac_2O, pyridine; (g) conc. HCl, MeOH.

acetate group in phosphine oxides **27**, **30** and **36** was unaffected by the strongly oxidising reaction conditions, and was easy to remove by acid-catalysed methanolysis,§ giving the required methyl esters **29**, **32** and **38** in good isolated yields over the two steps. We were particularly pleased that the phthalimide ring of **38** remained intact. Remarkably, we observed no epimerisation (by enolisation) of any of the products, despite the acidic conditions of the methanolysis step. The protection of the β-hydroxy phosphine oxides **32** and **38** as MOM acetals was very slow (though high yielding), reflecting the particularly hindered nature of the secondary alcohols (Scheme 6).¶ Unfortunately, the esters **39** and **40** did not react cleanly with a variety of organometallic and reducing reagents.

The final door to the strategy was closed with the discovery that phthalimide did not displace the secondary alcohol of **43** cleanly (Scheme 7). Instead, we isolated a single product which we believe to be allylic phosphine oxide **44**. This result was rather surprising in view of the many Mitsunobu reactions in which phthalimide replaces a secondary hydroxy group.[11] Perhaps the nearby electron-withdrawing diphenylphosphinoyl group promotes the elimination of intermediate **45**.

At this stage, this strategy was abandoned since no efficient way to functionalise the methyl ester groups stereoselectively (revealed by oxidative cleavage of the anisyl rings) had been found. Furthermore, most of the reaction sequences developed had been rather long because we could not find a protecting group which was stable to both ruthenium-catalysed oxidations and the nucleophilic reactions required by the second half of the route.

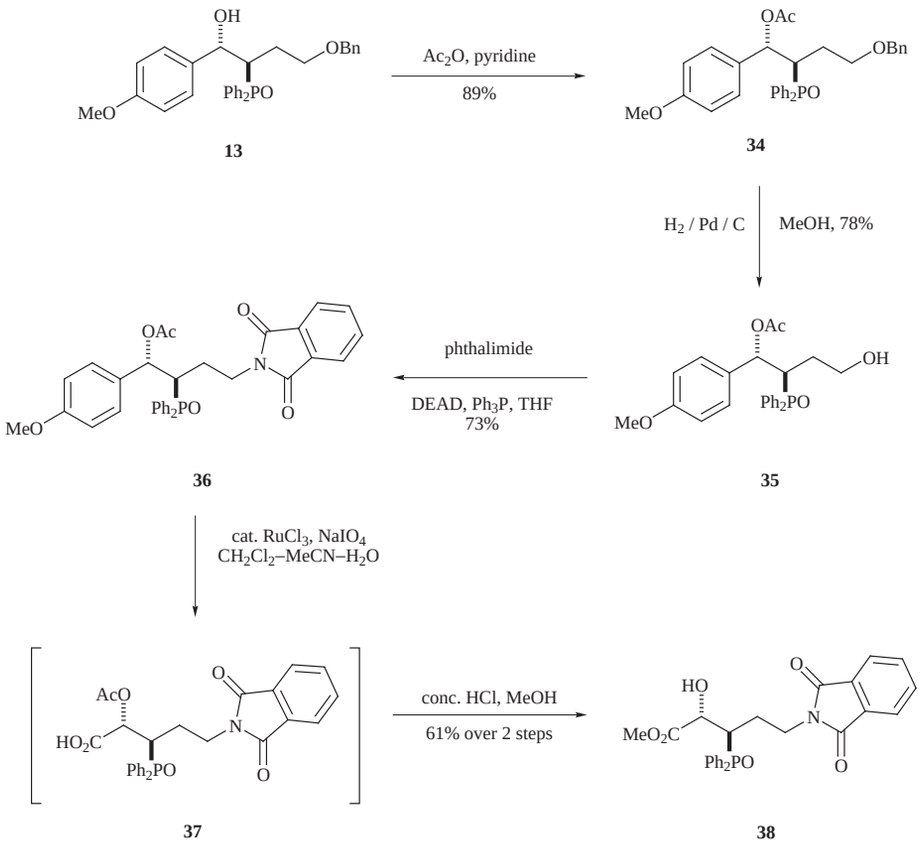
β-(2-Furyl) β-hydroxy phosphine oxides as masked β-hydroxy γ-keto phosphine oxides

Oxidation of the unprotected β-hydroxy phosphine oxide **46** with MCPBA gave the enone **47** as an 83 : 17 mixture of anomers (Scheme 8).‖ This oxidation had achieved exactly what

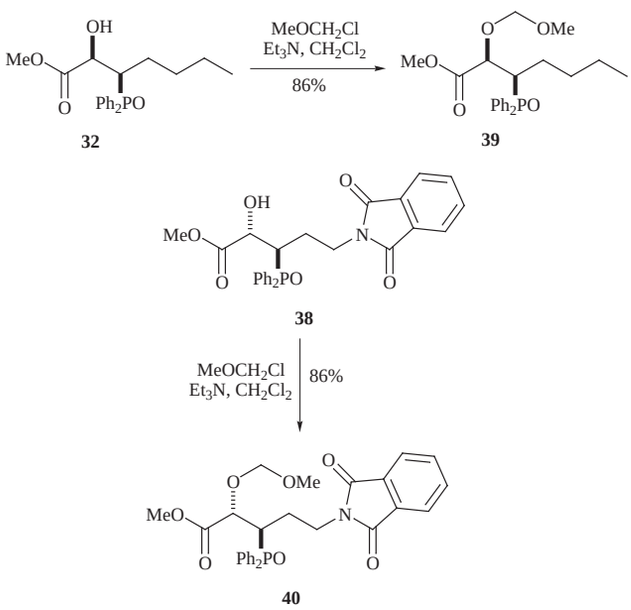
§ These conditions have been found to be the best conditions for the deprotection of β-acetoxy phosphine oxides (ref. 15).

¶ For examples of other β-hydroxy phosphine oxides which must be more hindered than most secondary alcohols, see ref. 15.

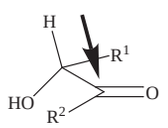
‖ For a review of furans in synthesis, see ref. 16. For examples of synthetic applications of furans, see ref. 17.



Scheme 5



Scheme 6



51 → 49

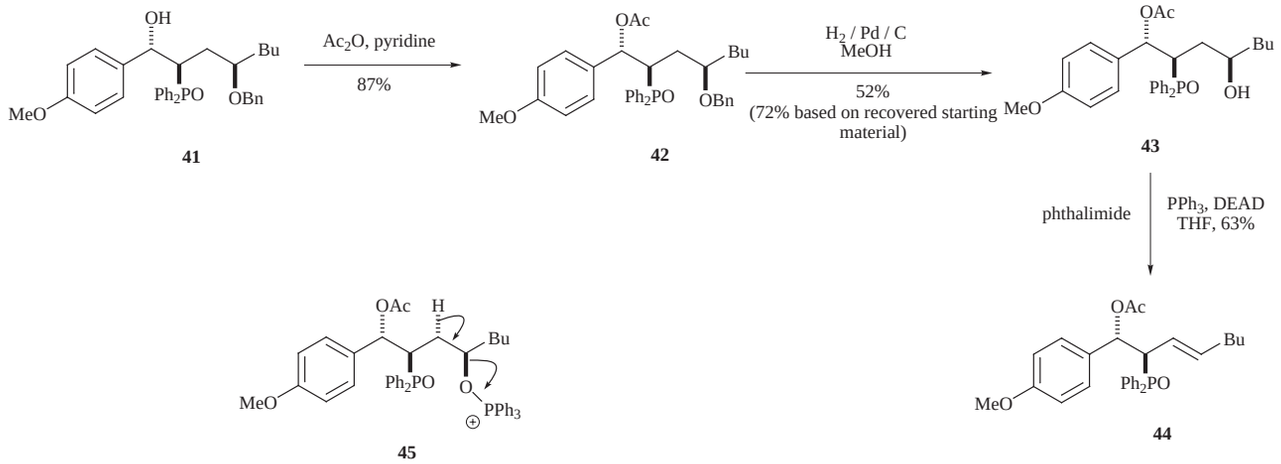
Fig. 2

we wanted; the furan ring of **46** had been transformed into a prochiral unit (a ketone) suitable for further functionalisation. Stereoselective functionalisation of the enone **47** was also surprisingly easy; the open-chain triol **49**, with its three controlled stereogenic centres, was obtained as a single diastereomer simply by reducing[18] **47** with sodium borohydride. Presumably, opening of the hemiacetal of **47** and reduction of the resulting aldehyde is followed by 1,4-addition and stereoselective 1,2-reduction of the enone.** Available evidence[20] suggests that such reactions are *syn* selective, and proceed under Felkin control (Fig. 2).[21]

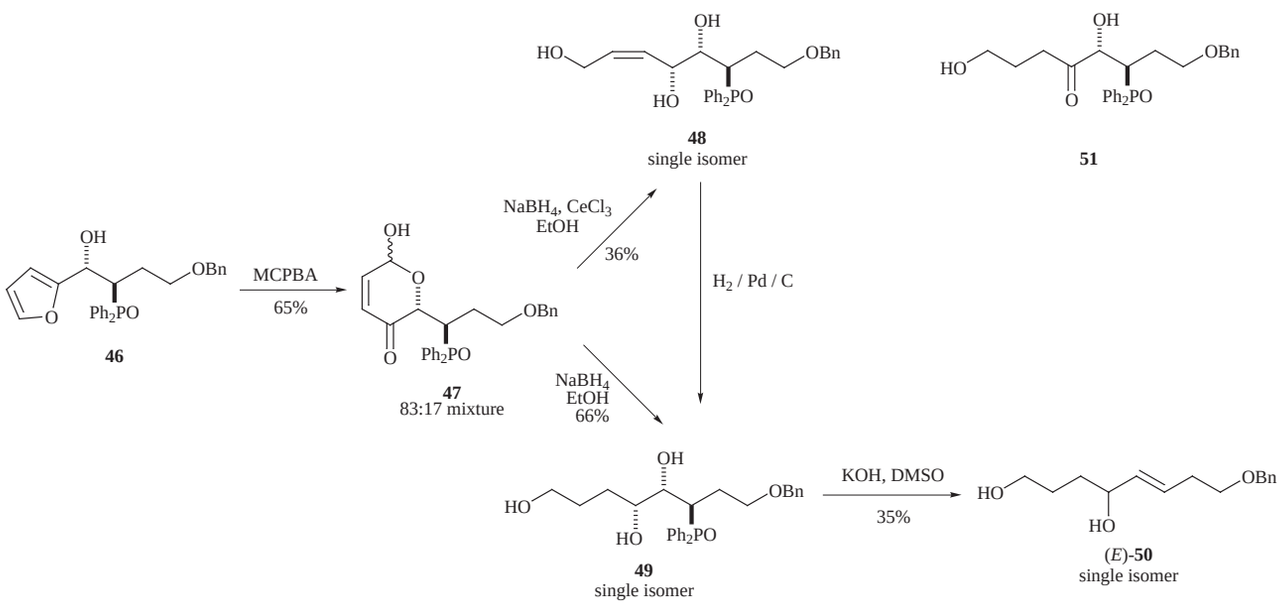
An obvious development of this work was to study the effect of cerium trichloride on the outcome of the reduction of **47**. Luche's reduction conditions[22] are well known to promote 1,2 reduction of α,β-unsaturated ketones, but the addition of the Lewis-acidic cerium trichloride can also dramatically alter the stereochemical course of reactions.[23] Reduction of enone **47** using Luche's conditions did indeed leave the double bond intact, and once more a single diastereomer (**48**) was obtained (Scheme 8). The stereochemistry of **48** was proved by catalytic hydrogenation to an 85:15 mixture of triol **49** and starting material. Evidently, the reduction of **47** with sodium borohydride in the presence of cerium(III) chloride proceeded with the same stereochemical sense as reduction with sodium borohydride alone.

Horner–Wittig elimination of **49** using potassium hydroxide in DMSO gave the alkene **50**, albeit in poor yield. Remarkably, alkene **50** was obtained as the (*E*) geometric isomer, indicating that the Horner–Wittig elimination had not been stereospecific. There are many examples of Horner–Wittig eliminations in which the usual *syn* stereospecificity has been lost,[24] and these examples are usually explained by a particularly easy retro-Horner–Wittig addition which can compete with the olefination process. In this case, however, we propose an alternative explanation which builds on other Horner–Wittig eliminations of β,γ-dihydroxy phosphine oxides.[13] Base-catalysed elimination of **49**, to give the vinyl phosphine oxide **52**, followed by readdition of hydroxide to give **53** would provide a means by

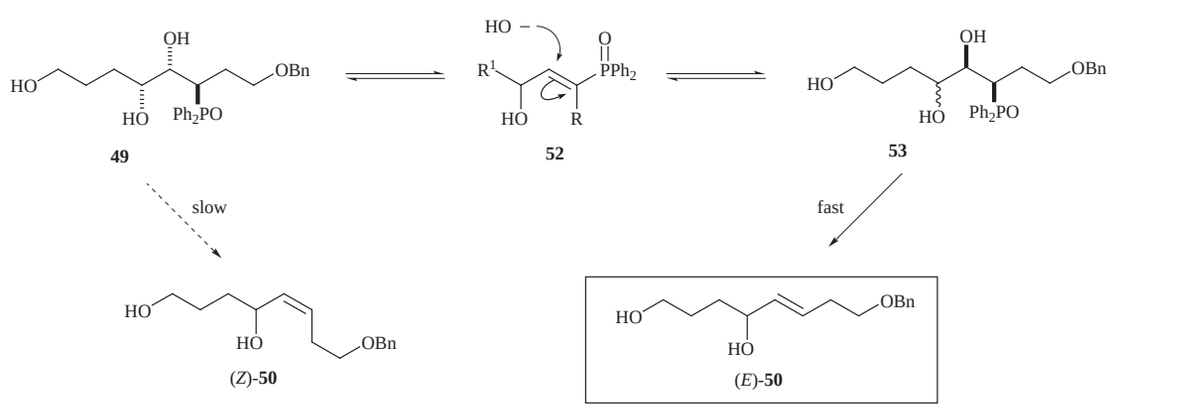
** The reduction of similar methyl acetals was completely 1,2-regioselective (ref. 19).



Scheme 7



Scheme 8



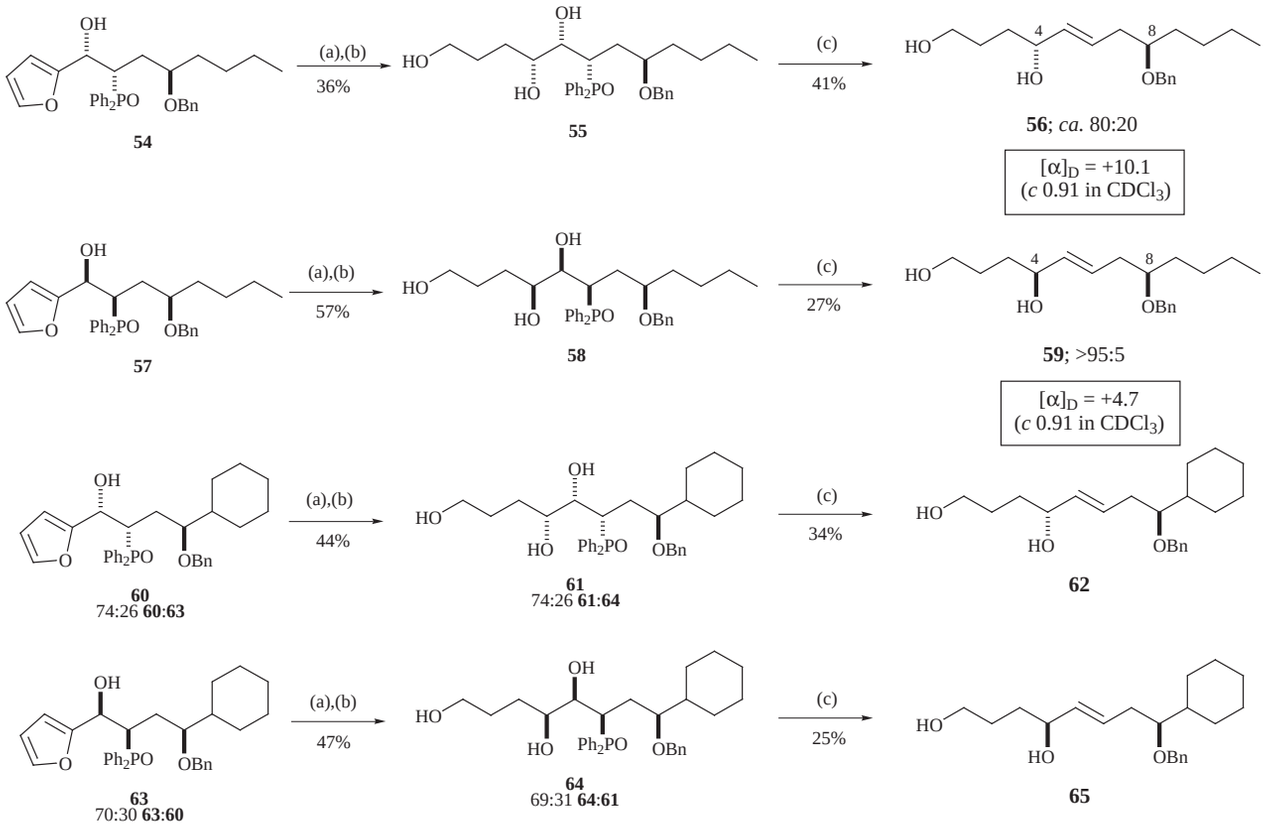
Scheme 9

which **49** could be converted into **53** under the reaction conditions (Scheme 9). Horner–Wittig elimination of **53** would then give the observed (*E*)-alkene **50**.

Synthesis of unsaturated diols with 1,5-related stereogenic centres across an *E* alkene

The stage was now set for the synthesis of some molecules with remote stereogenic centres across a double bond. Oxidation of the furan rings of **54** and **57**, followed by reduction with sodium borohydride introduced the fourth stereogenic centre of triols **55** and **58** with high stereoselectivity (Scheme 10). Previously, this sequence of reactions had been studied using the *anti* β-hydroxy phosphine oxide **46** (Scheme 8); we were pleased to find that reduction was equally stereoselective with *syn* phosphine oxides **54** and **57**.†† Removal of the middle two stereogenic centres of triols **55** and **58** by Horner–Wittig elimination was

†† A similarly remote stereogenic centre has been observed to have a remarkable effect on the rate and stereoselectivity of some diphenylphosphinoyl alkenes [ref. 3(*a*)].



Scheme 10 *Reagents and conditions*: (a) MCPBA, CH_2Cl_2; (b) $NaBH_4$, EtOH; (c) KOH, DMSO, 55 °C.

completely *E*-selective, giving unsaturated diols **56** and **59** in rather low yield.[25]

This approach was easily extended to cyclohexyl-substituted diols **62** and **65**.[25] Unfortunately, it was not possible to separate the *1,3syn* and *1,3anti* isomers **60** and **63**, so diols **62** and **65** were isolated as mixtures. Nevertheless, the 1,5-relationship between the stereogenic centres of diols **62** and **65** was partly (between 2:1 and 3:1) controlled which is a remarkable feat considering the remoteness (in space) of the stereogenic centres.

The conversion of **66** into the diol **56** was also studied and, once again, the Horner–Wittig elimination of an *anti* β-hydroxy phosphine oxide (**68**) gave an *E* alkene (Scheme 11). Nevertheless, the fact that our Horner–Wittig eliminations ignored the relative stereochemistry of the α and β stereogenic centres of **55**, **58** and **68** meant that both *1,5syn* and *1,5anti* diols **56** and **59** could be made from the same starting material **66**. This had been possible because **57** was synthesised from **66** using an oxidation–reduction sequence.[1]

Despite the inevitably *E*-selective Horner–Wittig elimination of the triols **55**, **58** and **68**, the use of single diastereomers throughout the reaction sequences described in Schemes 10 and 11 is still of fundamental importance. The stereochemistry of the β-hydroxy phosphine oxide unit of triols **55**, **58** and **68** still controlled the gradual transmission of stereochemical information from the stereogenic centre γ′ to phosphorus. The relative configuration of the β-hydroxy phosphine oxide unit may not determine the geometry of the alkene products, but these stereogenic centres still act as temporary "relay" centres.

Determining the diastereomeric purity of compounds with remote stereogenic centres is a very difficult task indeed.[26] Careful comparison of the 500 MHz ^{1}H NMR spectra of **56** and **59** allowed us to measure the diastereomeric purity of **59** confidently as >95:5. We derivatised the diols **56** and **59** as (*R*)-MTPA ("Mosher's") diesters. The diol **59** was essentially diastereomerically pure (>95:5), so the ratio of diastereomeric esters obtained (**70**:**71** 89:11) reflected the enantiomeric purity of **59**. The measured enantiomeric excess of **59** was 78%, which was the same (within experimental error) as that of the precursor[1] **74** (84% ee). The absolute stereochemistry of the stereogenic centre at C-4 (and hence the *relative* stereochemistry) of **59** was determined using Mosher's method[27] (Table 2).‡‡

Table 2 Chemical shift differences in Mosher's diesters **70**–**73**

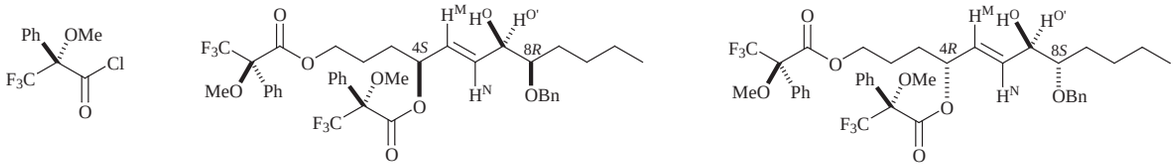
Entry	Mosher's diester X	Mosher's diester Y	$\delta(H^X–H^Y)$ H^M	H^N	$H^{O,O'}$
1	**70**	**71**	−0.08	−0.09	−0.03
2	**72**	**70**	+0.08	+0.08	+0.04

The diastereomeric purity of **56** was measured by conversion into the corresponding Mosher's diesters; the ratio of peaks in the 500 MHz ^{1}H NMR spectrum of these Mosher's esters was 74:26 which reflects the ratio of (4*R*):(4*S*) diols in the starting material (Table 2).[27] The diol was known to have 84% ee. The 74:26 ratio of peaks observed does not correspond to the known enantiomeric excess (which would require a ratio of 92:8) so **56** must be contaminated with its diastereoisomer **59** (*i.e.* **72** + **71**:**70** + **73** was 74:26). We estimate that the diastereomeric purity of **56** was 80:20.

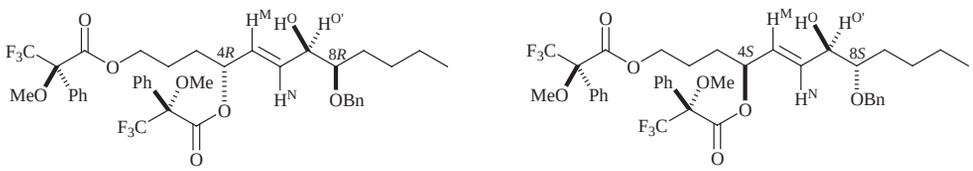
Summary

We have developed stereoselective methods which allow complete control over the stereochemistry of the products. In the preceding paper,[1] we described asymmetric syntheses of all four diastereomeric phosphine oxides **1** (R^2 = aryl). The work described in this paper allowed us to transform some aromatic R^2 groups in phosphine oxides **1** into prochiral units, by oxidative cleavage of either an anisyl ring or a furan ring, which were

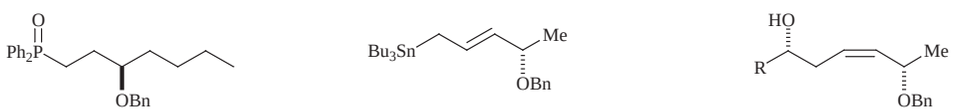
‡‡ Mosher's correlation has been applied to similar secondary allylic alcohols (ref. 28).



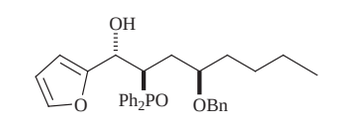
69 **70** **71**



72 **73**

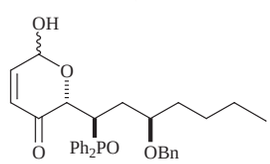


74 **75** **76**



66

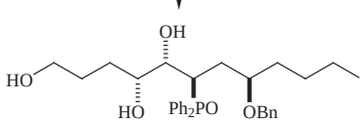
MCPBA, CH_2Cl_2, 95%



67

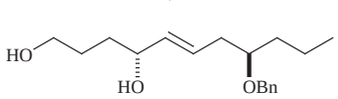
77:23 mixture

$NaBH_4$, EtOH, 68%



68

KOH, DMSO, 23%



56

Scheme 11

suitable for further functionalisation. Stereoselective reduction of the intermediate ketones gave the triols **55**, **58** and **68** with four controlled stereogenic centres. Horner–Wittig elimination of these triols was *E*-selective, yielding the diols **56** and **59** with 1,5-related stereogenic centres across an *E* alkene. This is the most remote chiral relationship which has been controlled using phosphine oxide chemistry. Our work is neatly complemented by some methodology which has been reported by Thomas; transmetallation of chiral allylic stannanes such as **75**, and reaction with aldehydes, gives homoallylic alcohols (*e.g.* **76**) with 1,5-related stereogenic centres across a (*Z*)-double bond.[29]

Experimental

General methods have been described previously.[1] Carbon NMR spectra were recorded with broad band proton decoupling and Attached Proton Test. Plus (+) and minus (−) symbols after the carbon NMR chemical shift indicate odd and even numbers of attached protons respectively.

(2*R**,3*S**,4*S**)-4-Diphenylphosphinoyl-1,2-epoxy-2-methyl-octan-3-ol 6

m-Chloroperbenzoic acid (57–85% by weight, 1.94 g, *ca.* 7.9 mmol) was added over 20 min to a stirred solution of (3*R**, 4*S**)-4-diphenylphosphinoyl-2-methyloct-1-en-3-ol[1] **5** (1.00 g, 2.8 mmol) and disodium hydrogen phosphate (2.16 g, 15.2 mmol) in dry dichloromethane (40 cm^3) at 0 °C. The reaction mixture was stirred for 16 h at 0 °C, quenched with sodium iodide (1.2 g, 7.9 mmol) and sodium thiosulfate (1.1 g, 7.9 mmol) and extracted with dichloromethane (3 × 30 cm^3). The combined organic extracts were washed with saturated sodium bicarbonate solution (30 cm^3) and brine (30 cm^3) and evaporated under reduced pressure to give the *epoxide* **6** (1.06 g, >98%, 95:5 ratio of diastereomers) as an oil, R_f 0.28 (EtOAc) (Found: MH^+, 359.1799. $C_{21}H_{27}O_3P$ requires *MH*, 359.1776); ν_{max}/cm^{-1} ($CHCl_3$) 3383 (br s, OH), 1438 (P–Ph) and 1161 (P=O); δ_H (400 MHz; $CDCl_3$) 7.9–7.75 (4 H, m), 7.6–7.25 (6 H, m, Ph_2PO), 4.07 (1 H, d, 11.4, C*H*OH), 3.70 (1 H, br s, OH), 2.99 (1 H, d, *J* 5.1, CH_AH_BO), 2.61 (1 H, d, *J* 5.1, CH_AH_BO), 2.44 (1 H, m, PCH), 1.89 (1 H, m), 1.62 (1 H, m), 1.31 (3 H, s, Me), 1.3–0.9 (4 H, m) and 0.66 (3 H, t, *J* 7.2, Me); δ_C (100 MHz; $CDCl_3$) 132–128 (m, Ph_2PO), 69.8$^+$ (CHOH), 57.9$^-$ (d, $^3J_{PC}$ 17.3, Me*C*), 51.3$^-$ (CH_2O), 40.2$^+$ (d, $^1J_{PC}$ 68.8, PCH), 32.1$^-$ (d, $^2J_{PC}$ 6.6), 22.8$^-$, 21.6$^-$, 18.7$^+$ (Me) and 13.6$^+$ (Me); *m*/*z* (FAB) 359.2 (60%, MH^+), 229.1 (80), 202.1 (100, Ph_2POH) and 201.1 (85, Ph_2POH).

(2*R**,3*S**,4*R**)-6-Benzyloxy-4-diphenylphosphinoyl-1,2-epoxy-2-methylhexan-3-ol 9

By the same general method, the allylic alcohol[1] **8** (547 mg, 1.36 mmol) gave the *epoxide* **9** (534 mg, 94%, 89:11 ratio of

diastereomers) as an oil, R_f 0.28 (EtOAc) (Found: $M^+ - C_3H_5O$, 379.1464. $C_{22}H_{29}O_3P$ requires $M - C_3H_5O$, 379.1463); ν_{max}/cm^{-1} ($CHCl_3$) 3389 (br s, OH), 1438 (P–Ph) and 1160 (P=O); δ_H (400 MHz; $CDCl_3$) 8.0–7.75 (4 H, m), 7.5–7.22 (6 H, m, Ph_2PO), 4.34 (1 H, d, *J* 11.9, PhCH_AH$_B$), 4.26 (1 H, d, *J* 11.9, PhCH$_A$$H_B$), 4.12 (1 H, d, *J* 11.2, C*H*OH), 3.81 (1 H, br s, OH), 3.35 (1 H, m, CH_AH$_B$OBn), 3.13 (1 H, m, CH$_A$$H_B$OBn), 3.05 (1 H, d, *J* 5.1, CH_AH$_B$O), 2.88 (1 H, dt, 5.5 and $^3J_{PH}$ 9.4, PCH), 2.54 (1 H, d, *J* 5.1, CH_AH$_B$O), 2.3–2.0 (2 H, m) and 1.27 (3 H, s, Me); δ_C (63 MHz; $CDCl_3$) 138.2$^-$ (*ipso*-Ph), 132–127 (m, Ph_2PO), 72.8$^-$ (O*C*H$_2$Ph), 69.3$^+$ (CHOH), 67.8$^-$ (d, $^3J_{PC}$ 6.8, Ph*C*H$_2$O), 57.9$^-$ (d, $^3J_{PC}$ 17.6, Me*C*O), 50.8$^-$ (CH_2O), 35.7$^+$ (d, $^1J_{PC}$ 69.9, PCH), 22.8$^-$ and 18.5$^+$ (Me); *m*/*z* 379.1463 (20%, $M^+ - C_3H_5O$), 271.1 (80) and 201.0 (100, Ph_2PO).

(2*R**,3*R**,4*S**)-4-Diphenylphosphinoyl-2-methyl-1-phenylsulfanyloctan-2,3-diol 7

n-Butyllithium (0.26 cm^3 of a 1.3 mol dm^{-3} solution in hexanes, 0.33 mmol) was added dropwise to a stirred solution of benzenethiol (37 µl, 0.36 mmol) in dry THF (10 cm^3). A solution of the phosphine oxide **6** (109 mg, 0.30 mmol) in dry THF (5 cm^3) was added dropwise by cannula to the reaction mixture which was stirred for 30 min, quenched with saturated ammonium chloride solution (15 cm^3) and extracted with dichloromethane (3 × 10 cm^3). The combined organic extracts were washed with saturated sodium bicarbonate solution (30 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product which was purified by flash chromatography eluting with 2:1 EtOAc–hexane to give the *diol* **7** (52 mg, 37%) as minute needles, mp 146–147 °C (from EtOAc–hexane); R_f 0.32 (3:2 EtOAc–hexane) (Found: C, 68.7; H, 7.05; P, 6.8%; MH$^+$, 469.1978. $C_{27}H_{33}O_3PS$ requires C, 69.2; H, 7.10; P, 6.6%; *MH*, 469.1966); ν_{max}/cm^{-1} ($CHCl_3$) 3346 (br s, OH), 1438 (P–Ph) and 1159 (P=O); δ_H (200 MHz; $CDCl_3$) 8.0–7.1 (15 H, m, Ph_2PO and PhS), 4.02 (1 H, br d, $^3J_{PH}$ 14.5, C*H*OH), 3.89 (1 H, br s, OH), 3.37 (1 H, d, *J* 13.4, CH_AH$_B$SPh), 3.05 (1 H, d, *J* 13.4, CH$_A$$H_B$SPh), 2.89 (1 H, s, OH), 2.69 (1 H, m, PCH), 2.5–0.9 (6 H, m), 1.27 (3 H, s, Me) and 0.58 (3 H, t, *J* 7.2, Me); δ_C (50 MHz; $CDCl_3$) 155.9$^+$ (*ipso*-Ph), 137–126 (m, Ph_2PO), 74.8$^-$ (d, $^3J_{PC}$ 13.3, *C*MeOH), 72.9$^+$ (CHOH), 44.6$^-$ (PhS*C*H$_2$), 37.4$^+$ (d, $^1J_{PC}$ 68.8, PCH), 32.4$^-$ and 22.8$^+$ (Me); *m*/*z* (FAB) 469.2 (80%, MH$^+$).

(2*R**,3*R**,4*S**)-6-Benzyloxy-4-diphenylphosphinoyl-2-methyl-1-phenylsulfanylhexane-2,3-diol 10

By the same general method, the epoxide **9** (480 mg, 1.15 mmol) gave a crude product which was purified by flash chromatography eluting with EtOAc, to give the *diol* **10** (465 mg, 77%, 72% from **8**) as plates, mp 141–142 °C (from EtOAc–hexane); R_f 0.32 (3:2 EtOAc–hexane) (Found: C, 69.9; H, 6.40; P, 5.8%; MH$^+$, 547.2076. $C_{32}H_{35}O_4PS$ requires C, 70.3; H, 6.45; P, 5.7%; *MH*, 547.2072); ν_{max}/cm^{-1} ($CHCl_3$) 3383 (br s, OH), 1438 (P–Ph) and 1160 (P=O); δ_H (400 MHz; $CDCl_3$) 7.85–7.1 (20 H, m, Ph_2PO and PhS), 4.40 (1 H, d, *J* 12.0, PhCH_AH$_B$), 4.21 (1 H, d, *J* 12.1, PhCH$_A$$H_B$), 4.08 (1 H, br s, OH), 4.06 (1 H, br d, $^3J_{PH}$ 14.0, C*H*OH), 3.34 (1 H, br s, OH), 3.30 (1 H, m, CH_AH$_B$OBn), 3.27 (1 H, d, *J* 13.0, CH_AH$_B$SPh), 3.17 (1 H, d, *J* 12.9, CH$_A$$H_B$SPh), 2.98 (1 H, m, CH$_A$$H_B$OBn), 2.87 (1 H, dt, *J* 4.4 and 9.5, PCH), 2.49 (1 H, m) and 1.89 (1 H, m); δ_C (50 MHz; $CDCl_3$) 137.8$^-$ (*ipso*-Ph), 136.9$^-$ (*ipso*-Ph), 132–125 (m, Ph_2PO), 75.0$^-$ (d, $^3J_{PC}$ 12.1, *C*H$_2$OBn), 72.6$^-$ (Ph*C*H$_2$), 72.9$^+$ (CHOH), 72.3$^+$ (CHOH), 68.3$^-$ (*C*MeOH), 43.7$^-$ (PhS*C*H$_2$), 34.1$^+$ (d, $^1J_{PC}$ 69.0, PCH), 23.1$^+$ (Me) and 22.3$^-$; *m*/*z* (FAB) 547.2 (70%, MH$^+$), 201.0 (80, Ph_2PO) and 91.1 (100, Bn).

(*Z*)-6-Benzyloxy-2-methyl-1-phenylsulfanylhex-3-en-2-ol 11

Sodium hydride (16 mg of a 60% dispersion in oil, 0.40 mmol) was added to a stirred solution of the diol **10** (51 mg, 96 µmol) in dry DMF (2 cm^3) at 20 °C. The reaction was stirred at 60 °C for 1 h, cooled to 20 °C, diluted with saturated brine (10 cm^3) and extracted into Et_2O (3 × 10 cm^3). The combined organic extracts were washed with water (10 cm^3) and saturated brine (10 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product which was purified by flash chromatography eluting with 4:1 hexane–EtOAc to give the *alkene* **11** (4.1 mg, 14%) as an oil, R_f 0.50 (3:1 hexane–EtOAc); ν_{max}/cm^{-1} ($CHCl_3$) 3500 (br s, OH), 1630 (C=C), 1437 (P–Ph) and 1160 (P=O); δ_H (400 MHz; $CDCl_3$) 7.4–7.1 (10 H, m, Ph and PhS), 5.59 (1 H, br d, *J* 12.1, C*H*=CHCH$_2$), 5.46 (1 H, td, *J* 8.2 and 11.8, CH=C*H*CH$_2$), 4.53 (2 H, AB q, *J* 12.1, PhCH_2), 3.81 (1 H, br s, OH), 3.50 (2 H, m, CH_2OBn), 3.17 (1 H, d, *J* 12.7, PhSCH_AH$_B$), 3.09 (1 H, d, *J* 12.7, PhSCH$_A$$H_B$), 2.74 (1 H, m), 2.59 (1 H, m) and 1.38 (3 H, s, Me); δ_C (100 MHz; $CDCl_3$) 136.9$^+$ (*C*H=CH), 129–127 (m, Ph and PhS), 125.9$^+$ (CH=*C*H), 73.7$^+$ (Me*C*OH), 73.2$^-$, 68.9$^-$, 48.3$^-$ (PhS*C*H$_2$), 28.9$^-$ and 28.4$^+$ (Me).

(1*R**,2*S**)-2-Diphenylphosphinoyl-1-(4-methoxyphenyl)hexyl acetate 27

(1*R**,2*S**)-2-Diphenylphosphinoyl-1-(4-methoxyphenyl)-hexan-1-ol[1] **16** (1.245 g, 3.05 mmol) was dissolved in pyridine (10 cm^3) and acetic anhydride (10 cm^3), and the reaction mixture was stirred for 3 days. The reaction was diluted with ethyl acetate (30 cm^3), washed with hydrochloric acid (2 × 30 cm^3), saturated aqueous sodium bicarbonate solution (30 cm^3), saturated brine (30 cm^3) and saturated aqueous copper(II) nitrate solution (30 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product. Purification by flash chromatography eluting with EtOAc gave the *ester* **27** (992 mg, 72%) as needles, mp 185–186 °C (from EtOAc–hexane); R_f 0.38 (EtOAc) (Found: C, 72.3; H, 7.00; P, 6.9%; M$^+$, 450.1952. $C_{27}H_{31}PO_4$ requires C, 72.0; H, 6.95; P, 6.9%; *M*, 450.1960); ν_{max}/cm^{-1} ($CHCl_3$) 1741 (C=O) and 1438 (P–Ph); δ_H (200 MHz; $CDCl_3$) 7.95–7.25 (10 H, m, Ph_2PO), 7.13 (2 H, d, *J* 8.7, Ar), 6.70 (2 H, d, *J* 8.7, Ar), 6.20 (1 H, dd, *J* 4.7 and 8.7, C*H*OAc), 3.68 (3 H, s, OMe), 2.73 (1 H, qd, *J* 5.0 and $^3J_{PH}$ 9.9, PCH), 2.0–0.85 (9 H, m) and 0.56 (3 H, t, *J* 6.7, Me); δ_C (50 MHz; $CDCl_3$) 169.2$^-$ (C=O), 158.9$^-$ (*ipso*-Ar), 133–127 (m, Ph_2PO and remaining Ph), 113.5$^+$ (Ar), 72.4$^+$ (C*H*OAc), 55.0$^+$ (OMe), 44.9$^+$ (d, $^1J_{PC}$ 67.8, PCH), 31.0$^-$ (d, $^2J_{PC}$ 6.8), 23.7$^-$, 22.3$^-$, 20.7$^+$ (OAc) and 13.2$^+$ (Me); *m*/*z* 450.1 (5%, M$^+$) and 202.1 (100, Ph_2POH).

(1*R**,2*R**)-2-Diphenylphosphinoyl-1-(4-methoxyphenyl)hexyl acetate 30

By the same general method, (1*R**,2*R**)-2-diphenylphosphinoyl-1-(4-methoxyphenyl)hexan-1-ol[1] **20** (2.20 g, 5.39 mmol), pyridine (17.5 cm^3) and acetic anhydride (17.5 cm^3) gave a crude product after 2 days. Purification by flash chromatography eluting with EtOAc gave the *ester* **30** (1.81 g, 75%) as an oil, R_f 0.47 (EtOAc) (Found: M$^+$, 450.1954. $C_{27}H_{31}PO_4$ requires *M*, 450.1960); ν_{max}/cm^{-1} ($CHCl_3$) 1738 (C=O), 1438 (P–Ph) and 1178 (P=O); δ_H (200 MHz; $CDCl_3$) 8.0–7.4 (10 H, m, Ph_2PO), 7.29 (2 H, d, *J* 8.6, Ar), 6.83 (2 H, d, *J* 8.6, Ar), 6.03 (1 H, dd, *J* 8.3 and 9.9, C*H*OAc), 3.74 (3 H, s, OMe), 2.96 (1 H, qd, *J* 4.8 and $^3J_{PH}$ 9.6, PCH), 1.6–0.8 (6 H, m), 1.3 (3 H, s, OAc) and 0.47 (3 H, t, *J* 6.7, Me); δ_C (50 MHz; $CDCl_3$) 168.2$^-$ (C=O), 159.3$^-$ (*ipso*-Ar), 135–128 (m, Ph_2PO and remaining Ph), 113.6$^+$ (Ar), 74.3$^+$ (C*H*OAc), 55.1$^+$ (OMe), 42.6$^+$ (d, $^1J_{PC}$ 68.5, PCH), 29.5$^-$ (d, $^2J_{PC}$ 6.0), 25.2$^-$, 22.3$^-$, 20.0$^+$ (OAc) and 13.1$^+$ (Me); *m*/*z* 450.1 (5%, M$^+$) and 202.1 (100, Ph_2POH).

(1*R**,2*S**)-4-Benzyloxy-2-diphenylphosphinoyl-1-(4-methoxyphenyl)butyl acetate 34

By the same general method, (1*R**,2*S**)-4-benxyloxy-2-diphenylphosphinoyl-1-(4-methoxyphenyl)butan-1-ol[1] **13** (3.48

g, 7.16 mmol), pyridine (25 cm^3) and acetic anhydride (25 cm^3) gave a crude product after 1 day. Purification by flash chromatography eluting with EtOAc gave the *ester* **34** (3.37 g, 89%) as an oil, R_f 0.33 (EtOAc) (Found: $M^+ - Ac$, 485.1882. $C_{32}H_{33}PO_5$ requires $M - Ac$, 485.1882); ν_{max}/cm^{-1} ($CHCl_3$) 1741 (C=O); 1438 (P–Ph) and 1193 (P=O); δ_H (200 MHz; $CDCl_3$) 8.0–7.25 (17 H, m, Ph_2PO, Ph and remaining Ar), 6.77 (2 H, d, *J* 8.7, Ar), 6.23 (1 H, dd, *J* 3.3 and 9.1, C*H*OAc), 4.01 (2 H, AB q, *J* 12.9, CH_2Ph), 3.73 (3 H, s, OMe), 3.2–2.9 (3 H, m, PCH and CH_2OBn) and 2.25 (2 H, m); δ_C (50 MHz; $CDCl_3$) 169.2$^-$ (C=O), 158.9$^-$, 155.7$^-$ (*ipso*-Ar and Ph), 133–126 (m, Ph_2PO and remaining Ph), 113.6$^+$ (Ar), 72.2$^-$ (O*C*H_2Ph), 71.7$^+$ (C*H*OAc), 67.9$^-$ (*C*H_2OBn), 55.1$^+$ (OMe), 40.5$^+$ (d, $^1J_{PC}$ 68.1, PCH), 34.0$^-$ and 20.7$^+$ (OAc); *m*/*z* 485.2 (5%, $M^+ - Ac$), 202.1 (100, Ph_2POH), 201.0 (75, Ph_2POH) and 91.1 (90, Bn).

(1*S*,2*R*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-(4-methoxyphenyl)octyl acetate 42

By the same general method, the phosphine oxide **41** (251 mg, 0.46 mmol), pyridine (2.5 cm^3) and acetic anhydride (2.5 cm^3) gave a crude product after 2 days. Purification by flash chromatography eluting with EtOAc gave the *ester* **42** (234 mg, 87%) as an oil, R_f 0.51 (EtOAc); $[a]_D^{20}$ +2.8 (*c* 0.91 in $CHCl_3$) (Found: M^+, 584.2691. $C_{36}H_{41}PO_5$ requires *M*, 584.2693); ν_{max}/cm^{-1} ($CHCl_3$) 1740 (C=O), 1438 (P–Ph) and 1192 (P=O); δ_H (200 MHz; $CDCl_3$) 7.9–7.2 (15 H, m, Ph_2PO and Ph), 7.13 (2 H, d, *J* 8.7, Ar), 6.76 (2 H, d, *J* 8.8, Ar), 6.15 (1 H, dd, *J* 2.9 and 10.5, C*H*OAc), 4.22 (1 H, d, *J* 12.0, PhCH_AH_B), 3.91 (1 H, d, *J* 12.0, PhCH_AH_B), 3.75 (3 H, s, OMe), 2.94 (1 H, m, C*H*OBn), 2.73 (1 H, quin, *J* 5.9, PCH), 2.1 (2 H, m), 1.98 (3 H, s, OAc), 1.3–0.9 (6 H, m) and 0.78 (3 H, t, *J* 7.3, Me); δ_C (50 MHz; $CDCl_3$) 169.4$^-$ (C=O), 159.0$^-$ (*ipso*-Ar), 139.1$^-$ (*ipso*-Ar), 134–127 (m, Ph_2PO, Ph and remaining Ar), 113.6$^+$ (Ar), 76.7$^+$ (d, *J* 4.0, C*H*OBn), 72.7$^+$ (C*H*OAc), 55.2$^+$ (OMe), 41.0$^+$ (d, $^1J_{PC}$ 67.8, PCH), 32.9$^-$, 28.2$^-$, 26.6$^-$, 22.6$^-$, 20.9$^+$ (OAc) and 13.9$^+$ (Me); *m*/*z* 587.1 (45%, M^+), 541.3 (80, $M - Ac$) and 232.1 (100).

(1*R**,2*S**)-2-Diphenylphosphinoyl-1-(4-methoxyphenyl)hexyl benzoate 17

Triethylamine (1.78 g, 17.4 mmol) and benzoyl chloride (2.17 g, 15.3 mmol) were added dropwise to a solution of (1*R**,2*S**)-2-diphenylphosphinoyl-1-(4-methoxyphenyl)hexan-1-ol **16** (1.245 g, 3.05 mmol) and *N*,*N*-dimethylaminopyridine (99 mg, 0.81 mmol) in dry dichloromethane (20 cm^3) at room temperature. The reaction was stirred for 3 days, quenched with water (20 cm^3), extracted with dichloromethane (3 × 20 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product. Purification by flash chromatography eluting with 2:1 EtOAc–hexane gave the *ester* **17** (1.51 g, 95%) as needles, mp 144–145 °C (from EtOAc–hexane); R_f 0.51 (EtOAc) (Found: C, 74.4; H, 6.70; P, 6.0%; M^+, 512.2114. $C_{32}H_{33}PO_4$ requires C, 74.4; H, 6.65; P, 6.2%; *M*, 512.2109); ν_{max}/cm^{-1} ($CHCl_3$) 1721 (C=O), 1438 (P–Ph) and 1212 (P=O); δ_H (200 MHz; $CDCl_3$) 8.01 (2 H, dd, *J* 1.3 and 7.2, *ortho*-Bz), 7.9–7.3 (13 H, m, Ph_2PO and remaining Bz), 7.13 (2 H, d, *J* 8.7, Ar), 6.71 (2 H, d, *J* 8.7, Ar), 6.32 (1 H, dd, *J* 4.8 and 8.5, C*H*OBz), 3.71 (3 H, s, OMe), 2.88 (1 H, qd, *J* 5.0 and $^2J_{PH}$ 10.1, PCH), 2.1–1.8 (2 H, m), 1.05 (4 H, m) and 0.62 (3 H, t, *J* 7.0, Me); δ_C (50 MHz; $CDCl_3$) 169.2$^-$ (C=O), 159.1$^-$ (*ipso*-Ar), 134–127 (m, Ph_2PO and remaining Ar and Bz), 113.7$^+$ (Ar), 73.8$^+$ (C*H*OBz), 55.2$^+$ (OMe), 45.2$^+$ (d, $^1J_{PC}$ 67.3, PCH), 31.0$^-$ (d, $^2J_{PC}$ 6.2), 24.1$^-$, 22.6$^-$ and 13.5$^+$ (Me); *m*/*z* 512.2 (10%, M^+) and 105 (100, PhCO).

(1*R**,2*R**)-2-Diphenylphosphinoyl-1-(4-methoxyphenyl)hexyl benzoate 21

By the same general method, (1*R**,2*R**)-2-diphenylphosphinoyl-1-(4-methoxyphenyl)hexan-1-ol[1] **20** (2.93 g, 7.18 mmol) gave a crude product after 2 days. Purification by flash chromatography eluting with 2:1 EtOAc–hexane gave the *ester* **21** (2.97 g, 81%) as needles, mp 181–183 °C (from EtOAc–hexane); R_f 0.53 (EtOAc) (Found: C, 74.4; H, 6.45; P, 6.1%; M^+, 512.2116. $C_{32}H_{33}PO_4$ requires C, 74.4; H, 6.65; P, 6.2%; *M*, 512.2109); ν_{max}/cm^{-1} ($CHCl_3$) 1719 (C=O) and 1438 (P–Ph); δ_H (400 MHz; $CDCl_3$) 8.12 (2 H, dd, *J* 1.3 and 8.5, *ortho*-Bz), 8.0–7.3 (13 H, m, Ph_2PO and remaining Bz), 7.18 (2 H, d, *J* 8.7, Ar), 6.82 (2 H, d, *J* 8.7, Ar), 6.38 (1 H, t, *J* 9.0, C*H*OBz), 3.86 (3 H, s, OMe), 3.13 (1 H, m, PCH), 1.7–0.8 (6 H, m) and 0.54 (3 H, t, *J* 7.4, Me); δ_C (63 MHz; $CDCl_3$) 164.9$^-$ (C=O), 159.4$^-$ (*ipso*-Ar), 135–126 (m, Ph_2PO and remaining Ar and Bz), 113.8$^+$ (Ar), 75.2$^+$ (C*H*OBz), 55.2$^+$ (OMe), 43.3$^+$ (d, $^1J_{PC}$ 68.1, PCH), 29.9$^-$ (d, $^2J_{PC}$ 5.9), 25.6$^-$, 24.6$^-$ and 13.4$^+$ (Me); *m*/*z* 512.2 (75%, M^+), 202.1 (85, Ph_2POH) and 105 (100, PhCO).

(1*R**,2*S**)-2-Diphenylphosphinoyl-1-(4-methoxyphenyl)propyl benzoate 25

By the same general method, (1*R**,2*S**)-2-diphenylphosphinoyl-1-(4-methoxyphenyl)propan-1-ol[1] **24** (451 mg, 31.23 mmol) gave a crude product after 2 days. Purification by flash chromatography eluting with 2:1 EtOAc–hexane gave the *ester* **25** (1.51 g, >98%) as needles, mp 165–166 °C (from EtOAc–hexane); R_f 0.51 (EtOAc) (Found: C, 73.5; H, 5.60; P, 6.6%; M^+, 470.1635. $C_{29}H_{27}PO_4$ requires C, 74.0; H, 5.80; P, 6.6%; *M*, 470.1647); ν_{max}/cm^{-1} ($CHCl_3$) 1723 (C=O) and 1438 (P–Ph); δ_H (200 MHz; $CDCl_3$) 7.95 (2 H, dd, *J* 1.3 and 7.2, *ortho*-Bz), 7.9–7.3 (13 H, m, Ph_2PO and remaining Bz), 7.15 (2 H, d, *J* 8.7, Ar), 6.72 (2 H, d, *J* 8.7, Ar), 6.39 (1 H, dd, *J* 4.8 and 8.5, C*H*OBz), 3.65 (3 H, s, OMe), 2.93 (1 H, qd, *J* 5.0 and $^2J_{PH}$ 10.1, PCH) and 1.30 (3 H, dd, *J* 7.3 and $^3J_{PH}$ 16.0, Me); δ_C (50 MHz; $CDCl_3$) 164.6$^-$ (C=O), 158.9$^-$ (*ipso*-Ar), 133–127 (m, Ph_2PO and remaining Ar and Bz), 113.6$^+$ (Ar), 73.1$^+$ (C*H*OBz), 54.9$^+$ (OMe), 39.7$^+$ (d, $^1J_{PC}$ 68.5, PCH) and 8.3$^+$ (Me); *m*/*z* 470.2 (80%, M^+), 365.1 (100, $M - PhCO$) and 202.1 (95, Ph_2POH).

(1*R**,2*S**)-2-Diphenylphosphinoyl-1-(4-methoxyphenyl)butane-1,4-diyl bis(benzyl ether) 14

Benzyl bromide (0.75 mmol) was added dropwise to a stirred solution of (1*R**,2*S**)-4-benzyloxy-2-diphenylphosphinoyl-1-(4-methoxyphenyl)butan-1-ol[1] (262 mg, 0.54 mmol), sodium hydride (28 mg, 60% dispersion in oil, 0.7 mmol) and tetra-*n*-butylammonium iodide (5 mg, 13 μmol) in dry THF (10 cm^3) at room temperature. The reaction was stirred for 3 days, quenched with water (10 cm^3), extracted with dichloromethane (3 × 10 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product. Purification by flash chromatography eluting with 1:1 EtOAc–hexane, to give the *dibenzyl ether* **14** (322 mg, >98%) as an oil, R_f 0.49 (EtOAc) (Found: $M^+ - Bn$, 485.1878. $C_{37}H_{37}O_4P$ requires $M - Bn$, 485.1882); ν_{max}/cm^{-1} ($CHCl_3$) 1437 (P–Ph) and 1201 (P=O); δ_H (200 MHz; $CDCl_3$) 8.0–7.1 (22 H, m, Ph_2PO, 2 × Ph and remaining Ar), 6.76 (2 H, br d, *J* 8.7, Ar), 5.01 (1 H, dd, *J* 4.3 and $^3J_{PH}$ 7.9, C*H*OBn), 4.37 (1 H, d, *J* 11.3, PhCH_AH_B), 4.18 (1 H, d, *J* 11.3, PhCH_AH_B), 4.10 (2 H, AB q, *J* 11.8, PhCH_2), 3.75 (3 H, s, OMe), 3.3–2.9 (2 H, m, CH_2OBn) and 2.3–2.1 (2 H, m); δ_C (50 MHz; $CDCl_3$) 158.9$^-$, 155.9$^-$, 138.4$^-$ (*ipso*-Ph), 138.0$^-$ (*ipso*-Ph), 134–127 (m, Ph_2PO and remaining Ar and 2 × Ph), 113.6$^+$ (Ar), 77.9$^+$ (*C*HOBn), 72.3$^-$, 70.7$^-$, 68.6$^-$ (d, $^3J_{PC}$ 17.0, CH_2OBn), 55.1$^+$ (OMe), 43.2$^+$ (d, $^1J_{PC}$ 68.4, PCH) and 24.5$^-$; *m*/*z* 485.2 (45%, $M^+ - Bn$) and 91.1 (100, Bn).

(1*R**,2*S**)-2-Diphenylphosphinoyl-4-hydroxy-1-(4-methoxyphenyl)butyl acetate 35

A solution of (1*R**,2*S**)-4-benzyloxy-2-diphenylphosphinoyl-1-(4-methoxyphenyl)butyl acetate **34** (510 mg, 0.97 mmol) and palladium on carbon (5% by weight, 48 mg) in methanol (20 cm^3) was degassed and flushed with argon, degassed and

flushed with hydrogen (×2), and stirred for 3 days under a hydrogen atmosphere. The reaction mixture was filtered through Celite with dichloromethane (50 cm^3) and evaporated under reduced pressure to give a crude product which was purified by flash chromatography eluting with 5% methanol in EtOAc, to give the *alcohol* **35** (330 mg, 78%) as minute needles, mp 164–165 °C (from EtOAc–hexane); R_f 0.43 (EtOAc) (Found: C, 68.4; H, 7.25; P, 8.0%; M^+, 438.1601. $C_{25}H_{27}O_5P$ requires C, 68.4; H, 7.20; P, 8.0%; *M*, 438.1596); ν_{max}/cm^{-1} ($CHCl_3$) 3379 (OH), 1743 (C=O) and 1438 (P–Ph); δ_H (400 MHz; $CDCl_3$) 7.9–7.4 (10 H, m, Ph_2PO), 7.07 (2 H, d, *J* 8.7, Ar), 6.74 (2 H, d, *J* 8.7, Ar), 6.13 (1 H, dd, *J* 3.9 and $^3J_{PH}$ 8.5, C*H*OAc), 3.72 (3 H, s, OMe), 3.63 (1 H, m), 3.48 (1 H, m), 3.00 (1 H, m), 2.08 (1 H, m), 2.04 (1 H, m) and 1.94 (3 H, s, OAc); δ_C (100 MHz; $CDCl_3$) 169.2$^-$ (C=O), 159.2$^-$ (*ipso*-Ar), 132–127 (m, Ph_2PO and remaining Ar), 114.0$^+$ (Ar), 72.3$^+$ (*C*HOAc), 60.4$^-$ (d, $^3J_{PC}$ 5.0, CH_2OH), 55.2$^+$ (OMe), 42.7$^+$ (d, $^1J_{PC}$ 66.8, PCH), 27.4$^-$ and 20.9$^+$ (OAc); *m*/*z* 438.2 (10%, M^+) and 202.1 (100, Ph_2POH).

(1*S*,2*R*,4*R*)-2-Diphenylphosphinoyl-4-hydroxy-1-(4-methoxyphenyl)octyl acetate 43

A solution of (1*S*,2*R*,4*R*)-4-benzyloxy-2-diphenylphosphinoyl-1-(4-methoxyphenyl)octyl acetate **42** (191 mg, 0.32 mmol) and palladium on carbon (5% by weight, 16 mg) in methanol (10 cm^3) was agitated under an atmosphere of hydrogen (4 atm) for 2 days, filtered through Celite with dichloromethane (50 cm^3) and evaporated under reduced pressure to give a crude product which was purified by flash chromatography eluting with EtOAc to give the *alcohol* **43** (84 mg, 52%, 72% based on recovered starting material) as minute needles, mp 170–171 °C (from EtOAc–hexane); R_f 0.22 (EtOAc) (Found: C, 70.3; H, 7.25; P, 6.2%; $M^+ - H$, 495.2295. $C_{29}H_{35}O_5P$ requires C, 70.4; H, 7.15; P, 6.2%; *M* − *H*, 495.2300); ν_{max}/cm^{-1} ($CHCl_3$) 3359 (OH), 1743 (C=O), 1438 (P–Ph) and 1176 (P=O); δ_H (400 MHz; $CDCl_3$) 7.9–7.4 (10 H, m, Ph_2PO), 7.07 (2 H, d, *J* 8.6, Ar), 6.73 (2 H, d, *J* 8.6, Ar), 6.12 (1 H, dd, *J* 4.3 and $^3J_{PH}$ 7.9, C*H*OAc), 3.75 (3 H, s, OMe), 3.70 (1 H, m), 3.56 (1 H, m), 3.06 (1 H, m, PCH), 2.2–0.95 (10 H, m) and 0.78 (3 H, t, *J* 7.3, Me); δ_C (100 MHz; $CDCl_3$) 169.2$^-$ (C=O), 159.1$^-$ (*ipso*-Ar), 132–126 (m, Ph_2PO and remaining Ar), 113.9$^+$ (Ar), 72.8$^+$ (*C*HOAc), 68.2$^+$ (CHOH), 55.2$^+$ (OMe), 42.3$^+$ (d, $^1J_{PC}$ 66.4, PCH), 37.3$^-$, 31.9$^-$, 27.8$^-$, 22.5$^-$, 21.0$^+$ (OAc) and 13.9$^+$ (Me); *m*/*z* 495.2 (10%, $M^+ - H$), 435.2 (100) and 201.1 (60, Ph_2PO). Recovered starting material was also obtained (51 mg, 27%).

(1*R**,2*S**)-2-Diphenylphosphinoyl-1-(4-methoxyphenyl)-4-phthalimidobutyl acetate 36

Diethyl azodicarboxylate (0.71 cm^3, 4.52 mmol) was added dropwise to a solution of (1*R**,2*S**)-2-diphenylphosphinoyl-4-hydroxy-1-(4-methoxyphenyl)butyl acetate **35** (1.34 g, 3.06 mmol), triphenylphosphine (1.20 g, 4.58 mmol) and phthalimide (532 mg, 3.64 mmol) in dry THF (60 cm^3) at 20 °C. The reaction was stirred for 16 h and evaporated under reduced pressure to give a crude product which was purified by flash chromatography eluting with 78:17:5 EtOAc–hexane–methanol and HPLC eluting with 0.8% methanol in chloroform, to give the *phthalimide* **36** (1.26 g, 73%) as an oil, HPLC retention time 19 min; R_f 0.34 (EtOAc) (Found: $M^+ - Ac$, 524.1617. $C_{33}H_{30}NO_6P$ requires *M* − *Ac*, 524.1627); ν_{max}/cm^{-1} ($CHCl_3$) 1770 (imide C=O), 1741 (C=O), 1708 (imide C=O) and 1438 (P–Ph); δ_H (400 MHz; $CDCl_3$) 8.0–7.4 (14 H, m, Ph_2PO and Ar), 6.98 (2 H, d, *J* 8.7, Ar), 6.43 (2 H, d, *J* 8.7, Ar), 6.11 (1 H, dd, *J* 3.3 and $^3J_{PH}$ 8.7, C*H*OAc), 3.48 (3 H, s, OMe), 3.28 (1 H, td, *J* 5.0 and 13.9, NCH_AH_B), 3.12 (1 H, ddd, *J* 5.0, 8.9 and 13.9, NCH_AH_B), 2.90 (1 H, qd, *J* 4.0 and $^2J_{PH}$ 9.2, PCH), 2.23 (2 H, m) and 1.99 (3 H, Ac); δ_C (50 MHz; $CDCl_3$) 169.3$^-$, 168.4$^-$ (C=O × 3), 158.7$^-$ (*ipso*-Ar), 155.8$^+$ (Ar), 133.5$^+$ (Ar), 134–128 (m, Ph_2PO and remaining Ar), 126.8$^+$ (Ar), 122.9$^+$ (Ar), 113.6$^+$ (Ar), 71.7$^+$ (*C*HOAc), 54.8$^+$ (OMe), 42.4$^+$ (d, $^1J_{PC}$ 67.0, PCH), 37.7$^-$ (d, $^3J_{PC}$ 5.2, CHN), 22.6$^-$ and 21.0$^+$ (OAc); *m*/*z* 524.2 (10%, $M^+ - Ac$), 202.1 (90, Ph_2POH) and 77.0 (100, Ph).

(1*S*,2*R*,3*E*)-2-Diphenylphosphinoyl-1-(4-methoxyphenyl)oct-3-enyl acetate 44

Diethyl azodicarboxylate (0.29 cm^3, 1.82 mmol) was added dropwise to a solution of (1*S*,2*R*,4*R*)-2-diphenylphosphinoyl-4-hydroxy-1-(4-methoxyphenyl)octyl acetate **43** (610 mg, 1.24 mmol), triphenylphosphine (493 mg, 1.88 mmol) and phthalimide (220 mg, 1.50 mmol) in dry THF (30 cm^3) at 20 °C. The reaction was stirred for 16 h and evaporated under reduced pressure to give a crude product which was purified by flash chromatography eluting with 1:1 EtOAc–hexane and then EtOAc to give the *allylic phosphine oxide* **44** (373 mg, 63%) as an oil, R_f 0.29 (EtOAc); $[\alpha]_D^{20}$ −1.7 (*c* 0.91 in $CHCl_3$) (Found: M^+, 476.2112. $C_{29}H_{33}O_4P$ requires *M*, 476.2116); ν_{max}/cm^{-1} ($CHCl_3$) 1740 (C=O), 1612 (C=C), 1437 (P–Ph) and 1176 (P=O); δ_H (200 MHz; $CDCl_3$) 7.9–7.1 (10 H, m, Ph_2PO), 7.08 (2 H, d, *J* 8.7, Ar), 6.68 (2 H, d, *J* 8.7, Ar), 6.20 (1 H, dd, *J* 4.5 and $^3J_{PH}$ 8.5, C*H*OAc), 5.05 (2 H, m, CH=CH), 3.71 (3 H, s, OMe), 2.86 (1 H, m), 2.52 (2 H, m), 1.98 (3 H, s, Ac), 1.9–1.75 (2 H, m), 1.15 (2 H, m) and 0.82 (3 H, t, *J* 7.3, Me); δ_C (50 MHz; $CDCl_3$) 169.2$^-$ (C=O), 159.0$^-$ (*ipso*-Ar), 132–127 (m, Ph_2PO and remaining Ar), 113.4$^+$ (Ar), 72.7$^+$ (*C*HOAc), 55.1$^+$ (OMe), 45.1$^+$ (d, $^1J_{PC}$ 68.1, PCH), 34.2$^-$, 28.6$^-$, 27.7$^-$, 22.2$^-$, 20.8$^+$ (Ac) and 13.6$^+$ (Me); *m*/*z* 476.2 (15%, M^+), 433 (40, M − Ac), 277 (100) and 201.1 (35, Ph_2PO).

(2*R**,3*S**)-2-Benzoyloxy-3-diphenylphosphinoylbutanoic acid 26

Sodium periodate (1.15 g, 5.4 mmol) was added to a stirred solution of the benzoate **25** (181 mg, 0.39 mmol) in 3:2:2 water–acetonitrile–carbon tetrachloride (3.5 cm^3). The reaction mixture was stirred until the phases were clear, ruthenium chloride (2 mg, 1 μmol) added, the reaction mixture stirred for 16 h, quenched with water (10 cm^3) extracted with dichloromethane (3 × 10 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product which was the *acid* **26**, R_f 0.0 (EtOAc) (Found: MH^+, 409.1210. $C_{23}H_{21}O_5P$ requires *MH*, 409.1205); ν_{max}/cm^{-1} ($CHCl_3$) 3600–2300 (OH), 1724 (C=O), 1438 (P–Ph) and 1199 (P=O); δ_H (400 MHz; $CDCl_3$) 10.25 (1 H, br s, CO_2H), 7.95–7.25 (15 H, m, Ph_2PO and Ph), 5.59 (1 H, dd, *J* 1.9 and $^3J_{PH}$ 9.8, C*H*OBz), 3.39 (1 H, dqd, *J* 1.9, 7.2 and $^2J_{PH}$ 10.5, PCH) and 1.38 (3 H, dd, *J* 7.2 and $^3J_{PH}$ 15.8, Me); δ_C (50 MHz; $CDCl_3$) 170.2$^-$, 169.9$^-$, 165.1$^-$, 133–128 (m, Ph_2PO and remaining Ar), 70.6$^+$ (*C*HOBz), 35.0$^+$ (d, $^1J_{PC}$ 69.9, PCH) and 7.4$^+$ (Me); *m*/*z* (FAB) 409.1 (100%, MH^+).

(1*R**,2*S**)-2-Diphenylphosphinoyl-1-(4-methoxyphenyl)butane-1,4-diyl dibenzoate 15

By the same general method, the diether **14** (55 mg, 95 μmol), sodium periodate (280 mg, 1.31 mmol) and ruthenium trichloride (3 mg, 1.5 μmol) gave a crude product which was purified by flash chromatography eluting with 3:1 EtOAc–hexane to give the diester **15** (8 mg, 14%) as an oil, R_f 0.52 (EtOAc); δ_H (200 MHz; $CDCl_3$) 8.1–7.1 (22 H, m, Ph_2PO and 2 × Bz), 6.73 (2 H, d, *J* 6.7, Ar), 6.35 (1 H, dd, *J* 3.5 and $^2J_{PH}$ 9.0, ArC*H*), 4.02 (2 H, t, *J* 5.1, CH_2OBz), 3.68 (3 H, s, OMe), 3.19 (1 H, m, PCH) and 2.50 (2 H, m).

(2*R**,3*S**)-2-Benzoyloxy-3-diphenylphosphinoylheptanoic acid 18

By the same general method, (1*R**,2*S**)-2-diphenylphosphinoyl-1-(4-methoxyphenyl)hexyl benzoate **17** (401 mg, 0.78 mmol), sodium periodate (2.54 g, 11.8 mmol) and ruthenium trichloride (3 mg, 1.5 μmol) gave a crude product which was

dissolved in ethyl acetate (10 cm^3) and extracted with saturated sodium bicarbonate solution (3 × 5 cm^3). The combined aqueous fractions were acidifed to pH 1, extracted with dichloromethane (3 × 5 cm^3) and the organic fractions were washed with brine (10 cm^3) to give the *acid* **18** (320 mg, 91%) as an oil, R_f 0.0 (EtOAc) (Found: M^+, 450.1624. $C_{26}H_{27}O_5P$ requires *M*, 450.1599); ν_{max}/cm^{-1} ($CHCl_3$) 3600–2800 (OH), 1721 (C=O) and 1438 (P–Ph); δ_H (400 MHz; $CDCl_3$) 10.25 (1 H, br s, CO_2H), 8.0–7.21 (15 H, m, Ph_2PO and Ph), 5.52 (1 H, br d, $^3J_{PH}$ 9.8, C*H*OBz), 3.32 (1 H, m, PCH), 2.1–0.8 (6 H, m) and 0.66 (3 H, t, *J* 6.7, Me); δ_C (50 MHz; $CDCl_3$) 170.6^- (d, $^3J_{PC}$ 5.6, CO_2H), 164.9^- (PhCO), 133–128 (m, Ph_2PO and Ar), 69.4^+ (*C*HOBz), 39.7^+ (d, $^1J_{PC}$ 69.0, PCH), 30.1^- (d, $^2J_{PC}$ 8.1), 23.4^-, 22.3^- and 13.4^+ (Me); *m*/*z* 450.2 (1%, M^+), 202.1 (100, Ph_2POH) and 105.0 (95, PhCO).

Methyl (2*R**,3*S**)-2-benzoyloxy-3-diphenylphosphinoylheptanoate 19

By the same general method, (1*R**,2*S**)-2-diphenylphosphinoyl-1-(4-methoxyphenyl)hexyl benzoate **17** (1.00 g, 1.96 mmol), sodium periodate (6.34 g, 29.6 mmol) and ruthenium trichloride (10 mg, 5 μmol) gave a crude product (950 mg). A portion of this product (143 mg) was dissolved in methanol (5 cm^3) and thionyl chloride (10 μl, 0.14 mmol) was added. The reaction mixture was stirred for 36 h, quenched with saturated sodium bicarbonate (5 cm^3), extracted with dichloromethane (3 × 5 cm^3), dried ($MgSO_4$) and evaporated to give a crude product which was purified by flash chromatography eluting with 1 : 1 EtOAc–hexane, to give the *ester* **19** (75 mg, 55%) as an oil, R_f 0.59 (EtOAc) (Found: M^+, 464.1722. $C_{27}H_{29}O_5P$ requires *M*, 464.1725); ν_{max}/cm^{-1} ($CHCl_3$) 1720 (C=O) and 1437 (P–Ph); δ_H (400 MHz; $CDCl_3$) 8.0–7.2 (15 H, m, Ph_2PO and Ph), 5.51 (1 H, dd, *J* 1.8 and $^3J_{PH}$ 11.3, C*H*OBz), 3.74 (3 H, s, OMe), 3.16 (1 H, dtd, *J* 1.8, 6.6 and $^2J_{PH}$ 11.2, PCH), 1.96 (2 H, m), 1.25 (4 H, m) and 0.79 (3 H, t, *J* 7.0, Me); δ_C (100 MHz; $CDCl_3$) 169.9^- (d, $^3J_{PC}$ 15.9, *C*O_2Me), 165.3^- (PhCO), 133–126 (m, Ph_2PO and Ar), 69.8^+ (*C*HOBz), 52.7^+ (OMe), 40.5^+ (d, $^1J_{PC}$ 68.5, PCH), 30.5^- (d, $^2J_{PC}$ 8.6), 23.7^-, 22.5^- and 13.7^+ (Me); *m*/*z* 464.2 (10%, M^+), 202.1 (70, Ph_2POH), 105.0 (100, PhCO) and 77 (65, Ph).

(2*R**,3*R**)-2-Benzoyloxy-3-diphenylphosphinoyl-*N*-methoxy-*N*-methylheptanamide 23

By the same general method, (1*R**,2*R**)-2-diphenylphosphinoyl-1-(4-methoxyphenyl)hexyl benzoate **21** (380 mg, 0.74 mmol), sodium periodate (2.31 g, 10.8 mmol) and ruthenium trichloride (4 mg, 2 μmol) gave a crude product (400 mg). A portion of this product (180 mg) was dissolved in dry dichloromethane (5 cm^3), carbonyldiimidazole (71 mg, 0.44 mmol) was added, the mixture was stirred for 10 min and *N*-methoxy-*N*-methylammonium chloride (46 mg, 0.46 mmol) was added. The reaction mixture was stirred for 16 h, diluted with dichloromethane (10 cm^3), washed with dilute hydrochloric acid (0.3 mol dm^{-3}, 2 × 10 cm^3), saturated sodium bicarbonate solution (10 cm^3) and brine (10 cm^3), dried ($MgSO_4$) and evaporated to give a crude product which was purified by flash chromatography eluting with 3 : 1 EtOAc–hexane to give the *amide* **23** (33 mg, 18%) as an oil, R_f 0.32 (EtOAc) (Found: M^+ − MeONMe, 433.1574. $C_{28}H_{32}NO_5P$ requires *M* − *MeONMe*, 433.1568); ν_{max}/cm^{-1} ($CHCl_3$) 1718 (C=O), 1664 (amide C=O), 1422 (P–Ph) and 1213 (P=O); δ_H (400 MHz; $CDCl_3$) 8.03–7.79 (4 H, m), 7.48–7.1 (11 H, m, Ph_2PO and remaining Ph), 6.02 (1 H, dd, *J* 8.4 and 12.8, C*H*OBz), 3.86 (3 H, s, OMe), 3.21 (1 H, m, PCH), 3.13 (3 H, s, NMe), 1.69 (2 H, m), 1.4–1.0 (4 H, m) and 0.71 (3 H, t, *J* 7.3, Me); δ_C (100 MHz; $CDCl_3$) 168.7^-, 165.8^-, 134–127 (m, Ph_2PO and Ar), 69.4^+ (*C*HOBz), 61.1^+ (OMe), 39.8^+ (d, $^1J_{PC}$ 69.4, PCH), 30.2^+ (NMe), 30.4^- (d, $^2J_{PC}$ 7.5), 24.4^-, 22.5^- and 13.5^+ (Me); *m*/*z* 433.2 (20%, M^+ − MeONMe) and 105.0 (100, PhCO).

Methyl (2*R**,3*S**)-3-diphenylphosphinoyl-2-hydroxyheptanoate 29

By the same general method, (1*R**,2*S**)-2-diphenylphosphinoyl-1-(4-methoxyphenyl)hexyl acetate **27** (505 mg, 1.12 mmol), sodium periodate (4.0 g, 18.7 mmol) and ruthenium trichloride (40 mg, 0.2 mmol) gave a crude product (550 mg) which was the *acid* **28**, R_f 0.0 (EtOAc) (Found: M^+, 390.1626. $C_{26}H_{29}O_4P$ requires *M*, 390.1596); ν_{max}/cm^{-1} ($CHCl_3$) 3700–2700 (OH), 1744 (C=O), 1438 (P–Ph) and 1205 (P=O); δ_H (400 MHz; $CDCl_3$) 7.9–7.3 (10 H, m, Ph_2PO), 6.4 (1 H, br s, CO_2H), 5.52 (1 H, dd, *J* 2.5 and $^3J_{PH}$ 14.9, C*H*OAc), 3.19 (1 H, m, PCH), 2.0–1.1 (6 H, m), 1.79 (3 H, s, OAc) and 0.75 (3 H, t, *J* 7.2, Me); δ_C (100 MHz; $CDCl_3$) 170.4^- (d, $^3J_{PC}$ 13.4, C=O), 169.6^- (Me*C*O), 132–128 (m, Ph_2PO), 69.5^+ (*C*HOAc), 39.8^+ (d, $^1J_{PC}$ 69.0, PCH), 30.3^- (d, $^2J_{PC}$ 10.0), 23.9^-, 22.4^-, 20.2^- (OAc) and 13.6^+ (Me); *m*/*z* 390.2 (10%, M^+), 294 (100) and 69.3 (100). A portion of the crude product (148 mg) was dissolved in methanol (10 cm^3), concentrated hydrochloric acid was added (4 cm^3) and the reaction stirred at 50 °C for 1 day. The reaction was quenched with water (10 cm^3), extracted with dichloromethane (3 × 10 cm^3), dried ($MgSO_4$) and evaporated to give a crude product, which was purified by flash chromatography eluting with 5% methanol in EtOAc to give the *ester* **29** (68 mg, 59%) as an oil, R_f 0.40 (EtOAc) (Found: M^+, 360.1490. $C_{20}H_{25}O_4P$ requires *M*, 360.1490); ν_{max}/cm^{-1} ($CHCl_3$) 3387 (OH), 1732 (C=O), 1438 (P–Ph) and 1221 (P=O); δ_H (400 MHz; $CDCl_3$) 7.95–7.4 (10 H, m, Ph_2PO), 4.63 (1 H, d, $^3J_{PH}$ 12.1, C*H*OH), 4.31 (1 H, br s, OH), 3.73 (3 H, s, OMe), 2.88 (1 H, m, PCH), 1.92 (1 H, m), 1.55 (1 H, m), 1.3–0.9 (4 H, m) and 0.71 (3 H, t, *J* 7.3, Me); δ_C (100 MHz; $CDCl_3$) 173.1^- (d, $^3J_{PC}$ 17.4, C=O), 132–128 (m, Ph_2PO), 68.8^+, 52.3^+ (OMe), 41.0^+ (d, $^1J_{PC}$ 68.9, PCH), 30.4^- (d, $^2J_{PC}$ 9.5), 22.5^-, 22.4^- and 13.6^+ (Me); *m*/*z* 360.1 (10%, M^+), 245.1 (60) and 202.1 (100, Ph_2POH).

Methyl (2*R**,3*S**)-3-diphenylphosphinoyl-2-hydroxyheptanoate 32

By the same general method, (1*R**,2*R**)-2-diphenylphosphinoyl-1-(4-methoxyphenyl)hexyl acetate **30** (1.02 g, 2.26 mmol), sodium periodate (8.0 g, 37.0 mmol) and ruthenium trichloride (100 mg, 0.5 mmol) gave a crude product (0.91 g) which was the acid **31**, R_f 0.0 (EtOAc) (Found: $M^+ - H$, 389.1511. $C_{26}H_{29}O_4P$ requires *M* − *H*, 389.1514); ν_{max}/cm^{-1} ($CHCl_3$) 3500–2500 (OH), 1742 (C=O), 1438 (P–Ph) and 1195 (P=O); δ_H (400 MHz; $CDCl_3$) 10.5–10.0 (1 H, br s, CO_2H), 7.9–7.4 (10 H, m, Ph_2PO), 5.53 (1 H, dd, *J* 2.3 and $^3J_{PH}$ 17.3, C*H*OAc), 3.14 (1 H, m, PCH), 1.81 (3 H, s, OAc), 1.65–1.1 (6 H, m) and 0.73 (3 H, t, *J* 7.1, Me); δ_C (100 MHz; $CDCl_3$) 169.5^-, 168.9^-, 133–128 (m, Ph_2PO), 70.1^+ (*C*HOAc), 40.5^+ (d, $^1J_{PC}$ 67.1, PCH), 30.0^- (d, $^2J_{PC}$ 10.9), 25.1^-, 21.9^-, 20.1^+ (OAc) and 13.4^+ (Me); *m*/*z* 389.2 (10%, $M^+ - H$) and 201.0 (Ph_2PO). The crude product was dissolved in methanol (60 cm^3), concentrated hydrochloric acid was added (20 cm^3) and the reaction was stirred at 50 °C for 1 day. The reaction was quenched with water (60 cm^3), extracted with dichloromethane (3 × 50 cm^3), dried ($MgSO_4$) and evaporated to give a crude product, which was purified by flash chromatography eluting with EtOAc to give the *ester* **32** (432 mg, 55%) as an oil, R_f 0.38 (EtOAc) (Found: M^+, 360.1490. $C_{20}H_{25}O_4P$ requires *M*, 360.1490); ν_{max}/cm^{-1} ($CHCl_3$) 3370 (OH), 1733 (C=O) and 1438 (P–Ph); δ_H (400 MHz; $CDCl_3$) 7.9–7.3 (10 H, m, Ph_2PO), 5.05 (1 H, d, *J* 8.8, OH), 4.50 (1 H, ddd, *J* 2.8, 8.7 and $^3J_{PH}$ 26.8, C*H*OH), 3.15 (3 H, s, OMe), 2.84 (1 H, tdd, *J* 2.7, 8.0 and 1.08, PCH), 2.0–1.1 (6 H, m) and 0.75 (3 H, t, *J* 6.9, Me); δ_C (100 MHz; $CDCl_3$) 173.2^-, 132–128 (m, Ph_2PO), 70.5^+ (d, $^2J_{PC}$ 4.5, CHOH), 51.6^+ (OMe), 40.0^+ (d, $^1J_{PC}$ 66.8, PCH), 29.5^- (d, $^2J_{PC}$ 11.1), 25.5^-, 22.0^- and 13.0^+ (Me); *m*/*z* 360.1 (50%, M^+), 301.1 (65, M^+ − MeCO) and 201.1 (100, Ph_2PO).

Methyl (2*R,3*S**)-3-diphenylphosphinoyl-2-hydroxy-5-phthalimidopentanoate 38**

By the same general method, (1*R**,2*S**)-2-diphenylphosphinoyl-1-(4-methoxyphenyl)-4-phthalimidobutyl acetate **36** (978 mg, 1.72 mmol), sodium periodate (7.62 g, 35.6 mmol) and ruthenium trichloride (10 mg, 5 μmol) gave a crude product which was the acid **37**, R_f 0.0 (EtOAc) (Found: MH^+, 506.1369. $C_{27}H_{24}NO_7P$ requires *MH*, 506.1398); ν_{max}/cm^{-1} ($CHCl_3$) 3800–2500 (OH), 1740–1650 (C=O) and 1206 (P=O); δ_H (400 MHz; $CDCl_3$) 8.70 (1 H, br s, CO_2H), 7.9–7.4 (14 H, m, Ph_2PO and Ar), 5.45 (1 H, dd, *J* 1.4 and $^3J_{PH}$ 13.2, C*H*OAc), 3.58 (1 H, m), 3.35 (1 H, m), 2.5–2.0 (3 H, m) and 1.98 (3 H, s, OAc); δ_C (100 MHz; $CDCl_3$) 170.4^- (d, $^3J_{PC}$ 13.2, C=O), 169.0^-, 168.0^-, 133.8^+ (Ar), 133–128 (m, Ph_2PO and remaining Ar), 128.2^+ (Ar), 116.4^- (Ar), 68.7^+ (*C*HOAc), 37.9^+ (d, $^1J_{PC}$ 70.8, PCH), 36.8^- (d, $^2J_{PC}$ 9.7), 23.4^- and 20.3^+ (OAc); *m*/*z* (FAB) 506.1 (80%, MH^+) and 307.1 (100). The crude product was dissolved in methanol (60 cm^3), concentrated hydrochloric acid was added (20 cm^3) and the reaction was stirred at 50 °C for 5 h. The reaction was quenched with water (60 cm^3), extracted with dichloromethane (3 × 50 cm^3), dried ($MgSO_4$) and evaporated to give a crude product, which was purified by flash chromatography eluting with EtOAc to give the *ester* **38** (412 mg, 61%) as an oil, R_f 0.38 (EtOAc) (Found: MH^+, 478.1538. $C_{26}H_{24}NO_6P$ requires *MH*, 478.1419); ν_{max}/cm^{-1} ($CHCl_3$) 3449 (OH), 1710 (C=O), 1438 (P–Ph) and 1219 (P=O); δ_H (400 MHz; $CDCl_3$) 8.0–7.3 (14 H, m, Ph_2PO and Ar), 4.66 (1 H, br s, OH), 4.62 (1 H, d, $^3J_{PH}$ 10.5, C*H*OH), 3.60 (3 H, s, OMe), 3.41 (1 H, td, *J* 5.5 and 14.0, NCH_AH_B), 3.22 (1 H, ddd, *J* 5.7, 8.9 and 14.0, NCH_AH_B), 3.01 (1 H, m, PCH) and 2.2 (2 H, m); δ_C (100 MHz; $CDCl_3$) 168.5^- (C=O × 3), 134–128 (m, Ph_2PO and remaining Ar), 123.1^+ (Ar), 113.6^+ (Ar), 70.2^+, 52.6^+ (OMe), 38.2^+ (d, $^1J_{PC}$ 68.7, PCH), 36.9^- (d, $^2J_{PC}$ 5.3) and 22.5^-; *m*/*z* 478.1 (FAB, MH^+), 279 (100, EI) and 201.1 (90, EI, Ph_2PO).

Methyl (2*R,3*S**)-2-benzoyloxy-3-diphenylphosphinoylheptanoate 19**

Diazomethane[30] (*ca.* 0.3 mol dm^{-3} in Et_2O) was added dropwise to a solution of acid **18** in ethyl acetate (6 cm^3) until a yellow colour persisted. The reaction was quenched by dropwise addition of acetic acid until the reaction mixture was colourless, and evaporated under reduced pressure to give a crude product which was purified by flash chromatography eluting with EtOAc, to give the *methyl ester* **19** (150 mg, 44%), identical spectroscopically with that obtained previously.

(2*R,3*S**)-3-Diphenylphosphinoylheptane-1,2-diol 33**

Methyl ester **19** (260 mg, 056 mmol) in dry THF (5 cm^3) was added by cannula dropwise to a stirred suspension of lithium aluminium hydride (127 mg, 3.36 mmol) in dry THF (5 cm^3) at 20 °C. The reaction was stirred for 2 h, quenched with water (10 cm^3), extracted with dichloromethane (3 × 10 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product which was purified by flash chromatography eluting with 5% methanol in EtOAc to give the *diol* **33** (96 mg, 52%) as an oil, R_f 0.23 (5% methanol in EtOAc) (Found: $M^+ - CH_2OH$, 301.1354. $C_{19}H_{25}O_3P$ requires $M - CH_2OH$, 301.1357); ν_{max}/cm^{-1} ($CHCl_3$) 3387 (OH), 1438 (P–Ph) and 1223 (P=O); δ_H (400 MHz; $CDCl_3$) 7.9–7.7 (4 H, m), 7.55–7.4 (6 H, m), 5.17 (1 H, m, C*H*OH), 3.79 (1 H, dd, *J* 5.6 and 11.3, CH_AH_BOH), 3.48 (1 H, dd, *J* 5.2 and 11.3, CH_AH_BOH), 3.38 (1 H, br s, OH), 2.47 (1 H, m, PCH), 1.84 (1 H, br s, OH), 1.8–1.0 (6 H, m) and 0.72 (3 H, t, *J* 7.3, Me); δ_C (100 MHz; $CDCl_3$) 133–128 (m, Ph_2PO), 70.8^+ (CHOH), 63.5^- (d, $^3J_{PC}$ 12.1, CH_2OH), 40.2^+ (d, $^1J_{PC}$ 68.9, PCH), 32.1^-, 32.9^-, 22.5^- and 13.5^+ (Me); *m*/*z* 301.1 (20%, $M^+ - CH_2OH$), 201.1 (100, Ph_2PO) and 77.0 (60, Ph).

Methyl (2*R,3*R**)-3-diphenylphosphinoyl-2-methoxymethoxyheptanoate 39**

Methoxymethyl chloride (0.22 cm^3, 0.29 mmol) and diisopropylethylamine (0.42 cm^3, 2.4 mmol) were added dropwise to a stirred solution of methyl (2*R**,3*S**)-3-diphenylphosphinoyl-2-hydroxyheptanoate **32** (218 mg, 0.61 mmol) in dry dichloromethane (5 cm^3) at 0 °C. The solution was stirred for 1 h, allowed to warm to room temperature, stirred for a further 7 days, quenched with aqueous saturated sodium carbonate (10 cm^3), extracted with dichloromethane (3 × 5 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude which was purified by flash chromatography eluting with EtOAc to give the *methoxymethyl ether* **39** (210 mg, 86%) as an oil, R_f 0.38 (EtOAc) (Found: M^+, 404.1742. $C_{22}H_{29}O_5P$ requires *M*, 404.1752); ν_{max}/cm^{-1} ($CHCl_3$) 1743 (C=O), 1437 (P–Ph), 1182 (P=O); δ_H (400 MHz; $CDCl_3$) 7.8–7.2 (10 H, m, Ph_2PO), 4.46 (1 H, d, *J* 7.0, $MeOCH_AH_B$), 4.42 (1 H, dd, *J* 6.6 and $^3J_{PH}$ 13.2, C*H*OMOM), 4.34 (1 H, d, *J* 7.0, $MeOCH_AH_B$), 3.59 (3 H, s, OMe), 2.99 (1 H, m, PCH), 1.7–1.0 (6 H, m) and 0.70 (3 H, t, *J* 7.2, Me); δ_C (50 MHz; $CDCl_3$) 133–128 (m, Ph_2PO), 96.7^- (OCH_2O), 75.3^+ (*C*HOMOM), 56.2^+, 52.0^+ (OMe × 2), 41.5^+ (d, $^1J_{PC}$ 69.8, PCH), 29.8^- (d, $^2J_{PC}$ 8.2), 25.3^-, 22.4^- and 13.6^+ (Me); *m*/*z* 404.2 (20%, M^+), 202.1 (100, Ph_2POH) and 201.1 (100, Ph_2PO).

Methyl (2*R,3*S**)-3-diphenylphosphinoyl-2-methoxymethoxy-5-phthalimidopentanoate 40**

By the same general method, methyl (2*R**,3*S**)-3-diphenylphosphinoyl-2-hydroxy-5-phthalimidopentanoate **38** (375 mg, 0.89 mmol), diisopropylethylamine (1.26 cm^3, 7.2 mmol) and methoxymethyl chloride (0.66 cm^3, 0.89 mmol) gave a crude product after 10 days which was purified by flash chromatography eluting with 2% methanol in EtOAc to give the *methoxymethyl ether* **40** (362 mg, 87%) as an oil, R_f 0.29 (EtOAc) (Found: MH^+, 522.1661. $C_{28}H_{28}NO_7P$ requires *MH*, 522.1682); ν_{max}/cm^{-1} ($CHCl_3$) 1772 (imide C=O), 1747 (C=O), 1712 (imide C=O), 1438 (P–Ph) and 1173 (P=O); δ_H (400 MHz; $CDCl_3$) 7.85–7.2 (14 H, m, Ph_2PO and Ar), 4.62 (3 H, m, $CHOCH_2OMe$), 3.63 (3 H, s, OMe), 3.45 (2 H, m), 3.26 (3 H, m, OMe), 2.94 (1 H, m) and 2.45–2.1 (2 H, m); δ_C (50 MHz; $CDCl_3$) 171.9^- (d, $^3J_{PC}$ 14.4, C=O), 167.9^- (C=O), 134–128 (m, Ph_2PO and remaining Ar), 122.9^+ (Ar), 96.4^- (OCH_2O), 72.1^+ (*C*HOMOM), 56.3^+, 52.1^+ (OMe × 2), 39.5^+ (d, $^1J_{PC}$ 69.2, PCH), 37.0^- (d, $^3J_{PC}$ 9.3) and 22.3^-; *m*/*z* (FAB) 522.1 (100%, MH^+), 279 (80), 201.1 (75, Ph_2PO) and 154.1 (100).

(2*R,6*R**,1′*S**)- and (2*S**,6*R**,1′*R**)-2-(3′-Benzyloxy-1′-diphenylphosphinoylpropyl)-6-hydroxy-3,6-dihydro-2*H*-pyran-3-one 47**

m-Chloroperbenzoic acid (328 mg, 57–85% by weight, *ca.* 1.34 mmol) was added to a stirred solution of (1*R**,2*S**)-4-benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)butan-1-ol[1] **46** (596 mg, 1.34 mmol) in dry dichloromethane (12 cm^3) at 0 °C. The reaction mixture was stirred for 2 days, diluted with dichloromethane (10 cm^3) washed with saturated sodium carbonate solution (20 cm^3), saturated sodium thiosulfate solution (20 cm^3) and saturated sodium carbonate solution (20 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product which was purified by flash chromatography eluting with 5% methanol in EtOAc to give the *enone* **47** (401 mg, 65%, 83 : 17 mixture of hemiacetal epimers) as a foam, R_f 0.25 (EtOAc) (Found: MH^+, 463.1644. $C_{27}H_{27}O_5P$ requires *MH*, 463.1674); ν_{max}/cm^{-1} ($CHCl_3$) 3268 (br, OH), 1696 (C=O), 1628 (C=C), 1438 (P–Ph) and 1166 (P=O); δ_H (400 MHz; $CDCl_3$) 8.0–7.8 (4 H, m), 7.6–7.2 (11 H, m, Ph_2PO and Ph), 6.96 (1 H, br d, *J* 10.2, $CH_A{=}CH_B^{min}$), 6.85 (1 H, dd, *J* 3.6 and 10.2, $CH_A{=}CH_B^{maj}$), 6.09 (1 H, br d, *J* 10.2, $CH_A{=}CH_B^{min}$),

5.99 (1 H, dd, *J* 1.0 and 10.3, CH_A=CH_B^{maj}), 5.62 (1 H, br s, OC*H*OH$^{maj+min}$), 4.91 (1 H, d, *J* 13.4, PCHC*H*O$^{maj+min}$), 4.28 (1 H, d, *J* 11.9, PhCH_AH$_B^{maj}$), 4.22 (1 H, d, *J* 11.9, PhCH$_A$$H_B^{maj}$), 3.75 (1 H, m, CH_AH_BOBn^{min}), 3.63 (1 H, br q, *J* 8.1, CH_AH_BOBn^{maj}), 3.4–3.2 (1 H, m, PCH and CH_AH_B-OBn$^{maj+min}$) and 2.3–2.0 (2 H, m); δ_C (100 MHz; $CDCl_3$) 195.7$^-$ (C=O), 151.0$^+$ (*C*H=CH^{min}), 146.6$^+$ (*C*H=CH^{maj}), 138.4$^-$ (*ipso*-Ph$^{maj+min}$), 132–126 (m, Ph_2PO and Ph), 91.3$^+$ (OCHO-H^{min}), 87.3$^+$ (OCHOH^{maj}), 76.3$^+$ (PCH*C*HO^{min}), 72.5$^-$ (*C*H$_2$Ph$^{maj+min}$), 68.1$^-$ (d, $^3J_{PC}$ 11.3, *C*H$_2$OBn$^{maj+min}$), 34.3$^+$ (d, $^1J_{PC}$ 72.8, PCH^{maj}), 24.1$^-$ (min) and 23.8$^-$ (maj); *m*/*z* (FAB) 463.3 (60%, MH$^+$) and 307.1 (100).

(2*S*,6*R*,1′*R*,3′*R*)- and (2*S*,6*S*,1′*R*,3′*R*)-2-(3′-Benzyloxy-1′-diphenylphosphinoylheptyl)-6-hydroxy-3,6-dihydro-2*H*-pyran-3-one 67

By the same general method, (1*S*,2*R*,4*R*)-4-benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)octan-1-ol[1] **66** (1.52 g, 3.02 mmol) and *m*-chloroperbenzoic acid (840 mg, 57–85% by weight, *ca.* 3.41 mmol) gave a crude product after 16 h which was purified by flash chromatography eluting with 5% methanol in EtOAc) to give the *enone* **67** (1.49 g, 95%, 77:23 mixture of hemiacetal epimers) as a foam, R_f 0.53 (10% methanol in EtOAc); $[a]_D^{20}$ +47.5 (*c* 0.20 in $CHCl_3$) (Found: MH$^+$, 519.2337. $C_{31}H_{35}O_5P$ requires *MH*, 519.2300); ν_{max}/cm^{-1} ($CHCl_3$) 3459 (OH), 1695 (C=O), 1601 (C=C), 1423 (P–Ph) and 1202 (P=O); δ_H (400 MHz; $CDCl_3$) 8.1–7.2 (4 H, m, Ph_2PO and Ph), 6.95 (1 H, br d, *J* 10.3, CH_A=CH$_B^{min}$), 6.80 (1 H, dd, *J* 3.3 and 10.2, CH_A=CH$_B^{maj}$), 6.03 (1 H, br d, *J* 10.3, CH$_A$=CH_B^{min}), 5.98 (1 H, d, *J* 10.2, CH$_A$=CH_B^{maj}), 5.80 (1 H, br s, OC*H*OH^{maj}), 5.20 (1 H, br s, OC*H*OH^{min}), 4.98 (1 H, d, *J* 14.4, PCHC*H*O$^{maj+min}$), 4.5–4.0 (2 H, m), 3.60 (1 H, m, C*H*OBn$^{maj+min}$), 3.00 (1 H, m, PCH$^{maj+min}$), 2.3 (2 H, m), 1.9 (2 H, m), 1.5–1.1 (4 H, m) and 0.90 (3 H, t, *J* 7.0, Me$^{maj+min}$); δ_C (100 MHz; $CDCl_3$) 195.4$^-$ (C=O^{maj}), 150.9$^+$ (*C*H=CH^{min}), 146.4$^+$ (*C*H=CH^{maj}), 139.2$^-$ (*ipso*-Ph^{maj}), 133–126 (m, Ph_2PO, CH=*C*H and Ph), 91.7$^+$ (OCHOH^{min}), 87.5$^+$ (OCHOH^{maj}), 76.6$^+$ (d, $^3J_{PC}$ 10.3, C*H*OBn), 71.8$^+$, 69.5$^-$ (*C*H$_2$Ph^{maj}), 60.4$^-$ (*C*H$_2$Ph^{min}), 36.5$^+$ (d, $^1J_{PC}$ 72.4, PCH$^{maj+min}$), 32.5$^-$, 27.9$^-$, 26.9$^-$ (maj), 22.6$^-$ (d, J_{PC} 4.3) and 14.2$^+$ (Me); *m*/*z* (FAB) 519.2 (65%, MH$^+$) and 201.0 (100, Ph_2PO).

(4*R**,5*S**,6*R**)-8-Benzyloxy-6-diphenylphosphinoyloctane-1,4,5-triol 49

Sodium borohydride (563 mg, 14.8 mmol) was added to a solution of **47** (943 mg, 2.11 mmol) in absolute ethanol (5 cm^3) and stirred for 16 h at room temperature. Hydrochloric acid (3.0 mol dm^{-3}, five drops) and water (10 cm^3) were added to the reaction mixture, the majority of the ethanol removed under reduced pressure, the aqueous suspension extracted with dichloromethane (3 × 10 cm^3), and the combined organic fractions dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product which was purified by flash chromatography eluting with 10% methanol in EtOAc to give the *triol* **49** (620 mg, 66%) as an oil, R_f 0.21 (7% methanol–EtOAc) (Found: M$^+$ − $C_4H_9O_2$, 379.1463. $C_{27}H_{33}O_5P$ requires *M* − $C_4H_9O_2$, 379.1463); ν_{max}/cm^{-1} ($CHCl_3$) 3425 (OH), 1438 (P–Ph) and 1199 (P=O); δ_H (400 MHz; $CDCl_3$) 8.0–7.2 (15 H, m, Ph_2PO and Ph), 4.57 (1 H, d, *J* 12.1, PhCH_AH$_B$), 4.28 (1 H, d, *J* 12.1, PhCH$_A$$H_B$), 3.79 (1 H, t, *J* 9.2, OCH_AH$_B$), 3.62 (1 H, quin, *J* 5.8), 3.57 (2 H, m), 3.37 (1 H, qd, *J* 1.4 and 7.0, C*H*OH), 2.84 (2 H, m, OCH and PCH), 2.30 (1 H, m), 1.97 (1 H, m), 1.83 (1 H, m), 1.77 (2 H, quin, *J* 6.5) and 1.33 (1 H, quin, *J* 8.6); δ_C (100 MHz; $CDCl_3$) 137.3$^-$ (*ipso*-Ph), 132–127.5 (m, Ph_2PO and Ph), 73.4$^+$ (CHOH), 72.8$^-$, 70.8$^+$ (d, $^3J_{PC}$ 11.5, CHOH), 69.6$^-$ (d, $^3J_{PC}$ 4.8, CHOBn), 62.4$^-$, 33.7$^+$ (d, $^1J_{PC}$ 70.3, PCH), 30.2$^-$, 29.1$^-$ and 21.0$^-$; *m*/*z* (FAB) 379.2 (65%, M$^+$ − $C_4H_9O_2$), 201.0 (100, Ph_2PO) and 91.0 (90, Bn).

(4*S*,5*S*,6*R*,8*R*)-8-Benzyloxy-6-diphenylphosphinoyldodecane-1,4,5-triol 68

By the same general method, enone **67** (1.35 g, 2.60 mmol) and sodium borohydride (691 mg, 18.2 mmol) gave a crude product which was purified by flash chromatography eluting with 10% methanol in EtOAc, to give the *triol* **68** (927 mg, 68%) as an oil, $[a]_D^{20}$ +17.3 (*c* 0.21 in $CHCl_3$) (Found: M$^+$ − $C_4H_9O_2$, 435.2102. $C_{31}H_{41}O_5P$ requires *M* − $C_4H_9O_2$, 435.2089); R_f 0.21 (7% methanol–EtOAc); ν_{max}/cm^{-1} ($CHCl_3$) 3441 (OH), 1438 (P–Ph) and 1160 (P=O); δ_H (400 MHz; $CDCl_3$) 7.7–7.1 (15 H, m, Ph_2PO and Ph), 4.68 (1 H, d, *J* 12.6, PhCH_AH$_B$), 4.25 (1 H, d, *J* 12.6, PhCH$_A$$H_B$), 3.73 (1 H, t, *J* 9.2, OCH_AH$_B$), 3.7–3.5 (3 H, m), 2.98 (1 H, t, *J* 5.8, C*H*OH), 2.6–2.5 (3 H, m), 2.1–1.85 (8 H, m), 0.80 (3 H, t, *J* 7.0, Me) and 0.50 (2 H, m); δ_C (100 MHz; $CDCl_3$) 137.3$^-$ (*ipso*-Ph), 132–126 (m, Ph_2PO and Ph), 76.1$^+$, 74.0$^+$, 71.1$^+$ (d, $^3J_{PC}$ 11.5, CHOH), 69.3$^-$, 63.0$^-$, 33.4$^+$ (d, $^1J_{PC}$ 70.8, PCH), 31.7$^-$, 30.3$^-$, 29.7$^-$, 26.5$^-$, 25.3$^-$, 22.5$^-$ and 14.0$^+$ (Me); *m*/*z* (FAB) 435.2 (65%, M$^+$ − $C_4H_9O_2$), 202.1 (80, Ph_2POH) and 91.0 (100, Bn).

(2*Z*,4*R**,5*S**,6*R**)-8-Benzyloxy-6-diphenylphosphinoyloct-2-ene-1,4,5-triol 48

Cerium trichloride heptahydrate (527 mg, 1.41 mmol) and enone **47** (590 mg, 1.28 mmol) were stirred in ethanol (25 cm^3) for 10 min and sodium borohydride (336 mg, 8.84 mmol) was added. The reaction mixture was stirred for 1 h, quenched with water (25 cm^3), extracted with dichloromethane (3 × 20 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product which was purified by flash chromatography eluting with 10% methanol in EtOAc to give the *triol* **48** (213 mg, 36%) as an oil, R_f 0.21 (7% methanol–EtOAc) (Found: M$^+$ − $C_4H_7O_2$, 379.1474. $C_{27}H_{31}O_5P$ requires *M* − $C_4H_7O_2$, 379.1463); ν_{max}/cm^{-1} ($CHCl_3$) 3421 (OH), 1654 (C=C) and 1438 (P–Ph); δ_H (400 MHz; $CDCl_3$) 7.80 (2 H, ddd, *J* 1.1, 7.7 and 8.8), 7.6–7.3 (13 H, m, Ph_2PO and Ph), 5.88 (1 H, td, *J* 7.0 and 11.0, CH_A=CH$_B$), 5.48 (1 H, dd, *J* 8.3 and 11.0, CH$_A$=CH_B), 4.92 (1 H, br s, OH), 4.53 (1 H, d, *J* 11.8, PhCH_AH$_B$), 4.52 (1 H, br s, OH), 4.32 (1 H, br s, OH), 4.30 (1 H, d, *J* 11.8, PhCH$_A$$H_B$), 4.13 (1 H, m), 3.97 (1 H, m), 3.82 (1 H, t, *J* 8.8), 3.55 (1 H, m), 3.40 (1 H, quin, *J* 4.0), 2.92 (2 H, m), 2.35 (1 H, m) and 1.85 (1 H, m); δ_C (100 MHz; $CDCl_3$) 137.3$^-$ (*ipso*-Ph), 133–127 (m, Ph_2PO and Ph), 73.1$^-$ (CH$_2$Ph), 72.5$^+$ (d, $^2J_{PC}$ 2.7, CHOH), 68.6$^-$ (d, $^3J_{PC}$ 5.0, CHOBn), 67.0$^+$ (d, $^3J_{PC}$ 11.6, CHOH), 58.3$^-$ (CH$_2$OH), 33.8$^+$ (d, $^1J_{PC}$ 70.0, PCH) and 21.0$^-$; *m*/*z* (FAB) 379.1 (55%, M$^+$ − $C_4H_7O_2$), 201.0 (100, Ph_2PO) and 91.1 (95, Bn).

Catalytic hydrogenation of 48

(2*Z*,4*R**,5*R**,6*S**)-8-Benzyloxy-6-diphenylphosphinoyloct-2-ene-1,4,5-triol **48** (76 mg, 0.16 mmol) and palladium on carbon (5% w/w, 8 mg) in ethyl acetate (5 cm^3) were stirred under an atmosphere of hydrogen (1 atm) for 4 h. The reaction mixture was filtered through Celite and evaporated under reduced pressure to give a crude product. Analysis of the crude product by ^{1}H NMR revealed an 85:15 mixture of **49** and starting material.

(4*S*,5*R*,6*R*,8*R*)-8-Benzyloxy-6-diphenylphosphinoyldodecane-1,4,5-triol 58

m-Chloroperbenzoic acid (202 mg, 57–85% by weight, *ca.* 0.82 mmol) was added to a stirred solution of the phosphine oxide **57** (365 mg, 0.73 mmol) in dry dichloromethane (8 cm^3) at 0 °C. The reaction mixture was stirred for 16 h, diluted with dichloromethane (10 cm^3), washed with saturated sodium carbonate solution (20 cm^3), saturated sodium thiosulfate solution (20 cm^3) and saturated sodium carbonate solution (20 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a residue, which was dissolved in ethanol (10 cm^3). Sodium

borohydride (173 mg, 4.6 mmol) was added to the the reaction mixture which was stirred for 1 h, quenched with water (10 cm^3) and the solvent removed under reduced pressure to give a residue which was diluted with water (20 cm^3), extracted with dichloromethane (3 × 20 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product which was purified by flash chromatography eluting with 10% methanol–EtOAc to give the *triol* **58** (180 mg, 57%) as an oil, R_f 0.21 (7% methanol–EtOAc); $[\alpha]_D^{20}$ −7.3 (*c* 0.20 in $CHCl_3$) (Found: $M^+ - C_4H_9O_2$, 435.2135. $C_{31}H_{41}O_5P$ requires $M - C_4H_9O_2$, 435.2089); ν_{max}/cm^{-1} ($CHCl_3$) 3389 (OH) and 1423 (P–Ph); δ_H (400 MHz; $CDCl_3$) 7.7–7.3 (15 H, m, Ph_2PO and Ph), 5.8* (1 H, br s, OH), 4.68 (1 H, d, *J* 12.1, $PhCH_AH_B$), 4.25 (1 H, d, *J* 12.1, $PhCH_AH_B$), 4.10* (1 H, br s, OH), 3.6 (5 H, m), 2.67 (1 H, m), 2.56 (1 H, m), 2.0–0.9 (11 H, m) and 0.76 (3 H, t, *J* 6.8, Me); δ_C (50 MHz; $CDCl_3$) 137.4$^-$ (*ipso*-Ph), 132–128 (m, Ph_2PO and Ph), 76.3$^+$, 73.5$^+$, 71.2$^+$, 69.8$^-$, 62.7$^-$, 40.2$^+$ (d, $^1J_{PC}$ 65.8, PCH), 31.9$^-$, 30.1$^-$, 29.0$^-$, 27.6$^-$, 26.6$^-$, 22.4$^-$ and 14.0$^+$ (Me); *m*/*z* (FAB) 435.2 (35%, $M^+ - C_4H_9O_2$), 216.1 (90) and 91.0 (100, Bn).

(4*R*,5*S*,6*S*,8*R*)-8-Benzyloxy-6-diphenylphosphinoyldodecane-1,4,5-triol 55

By the same general method, furan[1] **54** (1.24 g, 2.47 mmol), *m*-chloroperbenzoic acid (780 mg, 57–85% by weight, *ca.* 3.2 mmol) and sodium borohydride (253 mg, 6.7 mmol) gave a crude product which was purified by flash chromatography eluting with 10% methanol–EtOAc, to give the *triol* **55** (467 mg, 36%, 40% based on recovered starting material) as an oil, R_f 0.21 (7% methanol–EtOAc); $[\alpha]_D^{20}$ +7.1 (*c* 0.80 in $CHCl_3$) (Found: $M^+ - C_3H_7O$, 465.2195. $C_{31}H_{41}O_5P$ requires $M - C_3H_7O$, 465.2194); ν_{max}/cm^{-1} ($CHCl_3$) 3398 (OH), 1423 (P–Ph) and 1222 (P=O); δ_H (400 MHz; $CDCl_3$) 7.9–7.2 (15 H, m, Ph_2PO and Ph), 5.30 (1 H, br s, OH), 4.59 (1 H, d, *J* 11.1, $PhCH_AH_B$), 4.42 (1 H, d, *J* 11.1, $PhCH_AH_B$), 4.10 (1 H, OH), 3.7–3.45 (5 H, m), 3.21 (1 H, t, *J* 11.9), 2.10 (1 H, m), 2.0–1.0 (11 H, m) and 0.85 (3 H, t, *J* 7.3, Me); δ_C (100 MHz; $CDCl_3$) 138.0$^-$ (*ipso*-Ph), 132.5–128 (m, Ph_2PO and Ph), 74.5$^+$, 72.0$^+$, 71.4$^-$, 62.9$^-$ (one peak next to O missing), 37.2$^+$ (d, $^1J_{PC}$ 66.2, PCH), 32.6$^-$, 31.2$^-$, 29.9$^-$, 29.4$^-$, 27.2$^-$, 22.8$^-$ and 13.9$^+$ (Me); *m*/*z* (FAB) 465.2 (45%, $M^+ - C_3H_7O$), 202.1 (75, Ph_2POH), 201.1 (70, Ph_2PO) and 91.1 (100, Bn). Also obtained was starting material (110 mg, 11%), spectroscopically identical to that obtained previously.

(4*R*,5*S*,6*S*,8*S*)-8-Benzyloxy-8-cyclohexyl-6-diphenylphosphinoyloctane-1,4,5-triol 61

By the same general method, furan[1] **60** (270 mg, 0.51 mmol, 74:26 mixture of diastereomers), *m*-chloroperbenzoic acid (246 mg, 57–85% by weight, *ca.* 1.0 mmol) and sodium borohydride (135 mg, 3.6 mmol) gave a crude product which was purified by flash chromatography eluting with 10% methanol in EtOAc to give the *triol* **61** (121 mg, 44%, 74:26 mixture of diastereomers) as an oil, R_f 0.30 (10% methanol–EtOAc); $[\alpha]_D^{20}$ +19.0 (*c* 0.05 in $CHCl_3$) (Found: $M^+ - C_4H_9O_2$, 461.2242. $C_{33}H_{43}O_5P$ requires $M - C_4H_9O_2$, 461.2246); ν_{max}/cm^{-1} ($CHCl_3$) 3386 (OH) and 1438 (P–Ph); δ_H (400 MHz; $CDCl_3$) 7.9–7.2 (15 H, m, Ph_2PO and Ph), 5.78 (1 H, br s, OH^{min}), 5.69 (1 H, d, *J* 3.1, OH^{maj}), 5.08 (1 H, br s, OH^{maj}), 4.68 (1 H, d, *J* 11.1, $PhCH_AH_B^{min}$), 4.63 (1 H, d, *J* 12.1, $PhCH_AH_B^{maj}$), 4.28 (1 H, d, *J* 12.1, $PhCH_AH_B^{maj}$), 4.24 (1 H, d, *J* 11.1, $PhCH_AH_B^{min}$), 3.79 (1 H, m), 3.28 (3 H, m) and 2.1–0.4 (14 H, m); δ_C (100 MHz; $CDCl_3$) 137.5$^-$ (*ipso*-$Ph^{maj+min}$), 132–127.5 (m, Ph_2PO and Ph), 81.7$^+$ (maj), 81.0$^+$ (min), 74.9$^+$ (maj), 73.5$^+$ (min), 72.4$^-$ (maj), 72.1$^+$ (maj), 71.3$^+$ (min), 62.9$^-$ (min + min), 40.5$^+$ (d, $^1J_{PC}$ 66.2, PCH^{maj}), 40.1$^+$ (d, $^1J_{PC}$ 65.9, PCH^{min}) and 31–26 (several peaks); *m*/*z* (FAB) 461.2 (40%, $M^+ - C_4H_9O_2$), 201.0 (45, Ph_2PO) and 91.1 (100, Bn).

(4*S*,5*R*,6*R*,8*S*)-8-Benzyloxy-8-cyclohexyl-6-diphenylphosphinoyloctane-1,4,5-triol 64

By the same general method, the furan[1] **63** (382 mg, 0.73 mmol, 70:30 mixture of isomers), *m*-chloroperbenzoic acid (346 mg, 57–85% by weight, *ca.* 1.4 mmol) and sodium borohydride (194 mg, 5.1 mmol) gave a crude product which was purified by flash chromatography eluting with 10% methanol in EtOAc to give the *triol* **64** (186 mg, 47%, 69:31 mixture of diastereomers) as an oil, spectroscopically identical to that obtained previously, $[\alpha]_D^{20}$ −3.6 (*c* 1.01 in $CHCl_3$).

(*E*)-8-Benzyloxyoct-5-ene-1,4-diol 50

Potassium hydroxide (79 mg, 2.1 mmol) and (4*R**,5*S**,6*R**)-8-benzyloxy-6-diphenylphosphinoyloctane-1,4,5-triol **49** (201 mg, 0.43 mmol) were stirred in DMSO (10 cm^3) at 55 °C for 2 h. The reaction mixture was quenched with water (10 cm^3), extracted with Et_2O (3 × 10 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product which was purified by flash chromatography eluting with EtOAc to give the *alkene* **50** (37 mg, 35%) as an oil, R_f 0.77 (10% methanol–EtOAc) (Found: MH^+, 251.1626. $C_{15}H_{22}O_3$ requires *MH*, 251.1647); ν_{max}/cm^{-1} ($CHCl_3$) 3450 (OH) and 1654 (C=C); δ_H (400 MHz; $CDCl_3$) 7.4–7.25 (5 H, m, Ph), 5.66 (1 H, td, *J* 6.4 and 15.8, CH=C*H*CH_2), 5.55 (1 H, dd, *J* 6.6 and 15.5, C*H*=$CHCH_2$), 4.51 (2 H, s, $PhCH_2$), 4.09 (1 H, m, C*H*OH), 3.62 (2 H, m, CH_2O), 3.49 (2 H, t, *J* 6.2, CH_2O), 2.61 (2 H, br s, 2 × OH), 2.38 (2 H, q, *J* 6.6, CH=CHCH_2) and 1.62 (4 H, m); δ_C (100 MHz; $CDCl_3$) 138.4$^+$ (*ipso*-Ph), 134.9$^+$ (*C*H=CH), 128.8$^+$, 127.9$^+$, 72.9$^-$, 72.6$^+$ (CHOH), 69.7$^-$, 62.8$^-$, 34.2$^-$, 32.6$^-$ and 28.4$^-$; *m*/*z* (FAB) 251.2 (20%, MH^+) and 91.1 (100, Bn).

(4*S*,5*E*,8*R*)-8-Benzyloxydodec-5-ene-1,4-diol 59

By the same general method, (4*S*,5*R*,6*R*,8*R*)-8-benzyloxy-6-diphenylphosphinoyldodecane-1,4,5-triol **58** (129 mg, 0.25 mmol) and potassium hydroxide (45 mg, 1.18 mmol) gave a crude product which was purified by flash chromatography eluting with EtOAc to give the *alkene* **59** (20.6 mg, 27%) as an oil, R_f 0.38 (EtOAc); $[\alpha]_D^{20}$ +4.7 (*c* 0.91 in $CDCl_3$) (Found: $M^+ - OH$, 289.2173. $C_{19}H_{28}O_3$ requires $M - OH$, 289.2167); ν_{max}/cm^{-1} ($CHCl_3$) 3411 (br s, OH), 1642, 1602 and 1560 (C=C and Ph); δ_H (400 MHz; $CDCl_3$) 7.38–7.23 (5 H, m, Ph), 5.68 (1 H, td, *J* 7.0 and 15.5, CH=C*H*CH_2), 5.55 (1 H, dd, *J* 6.8 and 15.5, C*H*=$CHCH_2$), 4.52 (1 H, d, *J* 11.6, $PhCH_AH_B$), 4.48 (1 H, d, *J* 11.6, $PhCH_AH_B$), 4.10 (1 H, q, *J* 6.4, C*H*OH), 3.63 (2 H, m, CH_2OH), 3.42 (1 H, quin, *J* 7.1, CHOBn), 2.30 (2 H, t, *J* 6.2, CH=CHCH_2), 1.73 (1 H, br s, OH), 1.7–1.2 (10 H, m) and 0.90 (3 H, t, *J* 6.7, Me); δ_C (100 MHz; $CDCl_3$) 138.9$^-$ (*ipso*-Ph), 135.3$^+$ (*C*H=CH), 128.3$^+$, 127.9$^+$, 127.7$^+$, 127.5$^+$, 78.6$^+$, 72.7$^+$, 70.9$^-$, 62.9$^-$, 36.5$^-$, 34.2$^-$, 33.5$^-$, 28.9$^-$, 27.6$^-$, 22.7$^-$ and 14.1$^+$ (Me); *m*/*z* (FAB) 289.2 (20%, $M^+ - OH$) and 91.1 (100, Bn). Integration of the 500 MHz NMR spectrum of the Mosher's diester[31] of this material indicated a ratio of (4*S*):(4*R*) stereoisomers of 89:11.

(4*R*,5*E*,8*R*)-8-Benzyloxydodec-5-ene-1,4-diol 56

By the same general method, (4*R*,5*S*,6*S*,8*R*)-8-benzyloxy-6-diphenylphosphinoyldodecane-1,4,5-triol **55** (174 mg, 0.34 mmol) and potassium hydroxide (61 mg, 1.61 mmol) gave a crude product which was purified by flash chromatography eluting with EtOAc to give the *alkene* **56** (41.2 mg, 41%) as an oil, R_f 0.38 (EtOAc); $[\alpha]_D^{20}$ +10.1 (*c* 0.91 in $CDCl_3$) (Found: $M^+ - C_4H_{10}O_2$, 216.1515. $C_{19}H_{28}O_3$ requires $M - C_4H_{10}O_2$, 216.1514); ν_{max}/cm^{-1} ($CHCl_3$) 3422 (br s, OH), 1642, 1602 and 1560 (C=C and Ph); δ_H (400 MHz; $CDCl_3$) 7.36–7.23 (5 H, m, Ph), 5.66 (1 H, td, *J* 7.0 and 15.4, CH=C*H*CH_2), 5.53 (1 H, dd, *J* 6.7 and 15.4, C*H*=$CHCH_2$), 4.52 (1 H, d, *J* 11.7, $PhCH_AH_B$), 4.46 (1 H, d, *J* 11.7, $PhCH_AH_B$), 4.08 (1 H, m, C*H*OH), 3.62 (2 H, m, CH_2OH), 3.44 (1 H, m, CHOBn), 2.55 (1 H, br s, OH),

2.29 (2 H, m, CH=CHCH_2), 1.65–1.2 (10 H, m) and 0.88 (3 H, t, *J* 6.7, Me); δ_C (100 MHz; $CDCl_3$) 138.8$^-$ (*ipso*-Ph), 135.3$^+$ (*C*H=CH), 128.3$^+$, 127.8$^+$, 127.7$^+$, 127.5$^+$, 78.6$^+$, 72.7$^+$, 70.9$^-$, 62.8$^-$, 36.5$^-$, 34.3$^-$, 33.5$^-$, 28.9$^-$, 27.6$^-$, 22.8$^-$ and 14.1$^+$ (Me); *m*/*z* 216.2 (45%, $M^+ - C_4H_{10}O_2$), 105.0 (80) and 91.1 (100, Bn). Integration of the 500 MHz NMR spectrum of the Mosher's diester[31] of this material indicated a ratio of (4*R*):(4*S*) stereoisomers of 74:26.

(4*R*,5*E*,8*S*)-8-Benzyloxy-8-cyclohexyloct-5-ene-1,4-diol 62

By the same general method, (4*R*,5*S*,6*S*,8*S*)-8-benzyloxy-8-cyclohexyl-6-diphenylphosphinoyloctane-1,4,5-triol **61** (105 mg, 0.19 mmol) and potassium hydroxide (34 mg, 0.89 mmol) gave a crude product which was purified by flash chromatography eluting with EtOAc, to give the *alkene* **62** (21.2 mg, 34%) as an oil, R_f 0.36 (EtOAc); $[\alpha]_D^{20}$ +6.4 (*c* 0.89 in $CHCl_3$) (Found: MNa^+, 355.2261. $C_{21}H_{32}O_3$ requires *MNa*, 355.2249); ν_{max}/cm^{-1} ($CHCl_3$) 3407 (OH) and 1662 (C=C); δ_H (400 MHz; $CDCl_3$) 7.4–7.25 (5 H, m, Ph), 5.76 (1 H, td, *J* 7.1 and 15.4, CH=C*H*CH$_2$), 5.51 (1 H, dd, *J* 6.7 and 15.4, C*H*=CHCH$_2$), 4.52 (1 H, d, *J* 11.5, PhCH_AH_B), 4.40 (1 H, d, *J* 11.5, PhCH_AH_B), 4.11 (1 H, m, C*H*OH), 3.62 (2 H, m, CH_2OH), 3.19 (1 H, q, *J* 5.3, CHOBn), 2.35 (2 H, m, CH=CHCH_2), 1.9–0.9 (15 H, m); δ_C (100 MHz; $CDCl_3$) 138.9$^-$ (*ipso*-Ph), 134.9$^+$ (*C*H=CH), 128.2$^+$, 127.9$^+$, 127.7$^+$, 127.5$^+$, 83.3$^+$, 72.7$^+$, 71.8$^-$, 62.9$^-$, 41.0$^+$ (*C*HCHOBn), 34.2$^-$, 33.5$^-$, 33.4$^-$, 29.0$^-$, 28.9$^-$, 28.7$^-$, 26.6$^-$ and 26.3$^-$; *m*/*z* 203.1 (100%, CHOBn^{c}Hex), 111.1 (90) and 91.1 (100, Bn).

(4*S*,5*E*,8*S*)-8-Benzyloxy-8-cyclohexyloct-5-ene-1,4-diol 65

By the same general method, (4*S*,5*R*,6*R*,8*S*)-8-benzyloxy-8-cyclohexyl-6-diphenylphosphinoyloctane-1,4,5-triol **64** (140 mg, 0.25 mmol) and potassium hydroxide (44 mg, 1.16 mmol) gave a crude product which was purified by flash chromatography eluting with EtOAc to give the *alkene* **65** (20.6 mg, 25%) as an oil, R_f 0.36 (EtOAc); $[\alpha]_D^{20}$ +8.6 (*c* 0.45 in $CHCl_3$) (Found: MNa^+, 355.2261. $C_{21}H_{32}O_3$ requires *MNa*, 355.2249); ν_{max}/cm^{-1} ($CHCl_3$) 3413 (OH) and 1669 (C=C); δ_H (400 MHz; $CDCl_3$) 7.4–7.25 (5 H, m, Ph), 5.76 (1 H, td, *J* 7.1 and 15.4, CH=C*H*CH$_2$), 5.51 (1 H, dd, *J* 6.7 and 15.4, C*H*=CHCH$_2$), 4.52 (1 H, d, *J* 11.5, PhCH_AH_B), 4.49 (1 H, d, *J* 11.5, PhCH_AH_B), 4.11 (1 H, m, C*H*OH), 3.62 (2 H, m, CH_2OH), 3.19 (1 H, q, *J* 5.3, C*H*OBn), 2.35 (2 H, m, CH=CHCH_2) and 1.9–0.9 (15 H, m); δ_C (100 MHz; $CDCl_3$) 138.9$^-$ (*ipso*-Ph), 135.0$^+$ (*C*H=CH), 128.2$^+$, 127.9$^+$, 127.8$^+$, 127.5$^+$, 83.4$^+$, 72.7$^+$, 71.8$^-$, 62.9$^-$, 41.0$^+$ (*C*HCHOBn), 34.2$^-$, 33.5$^-$, 33.4$^-$, 29.0$^-$, 28.9$^-$, 28.7$^-$, 26.6$^-$, 26.4$^-$ and 26.3$^-$; *m*/*z* 203.1 (100%, CHOBn^{c}Hex), 111.1 (90) and 91.1 (100, Bn).

(4*R*,5*E*,8*R*)-8-Benzyloxydodec-5-ene-1,4-diol 56

By the same general method, (4*R*,5*S*,6*R*,8*R*)-8-benzyloxy-6-diphenylphosphinoyldodecane-1,4,5-triol **68** (306 mg, 0.58 mmol) and potassium hydroxide (107 mg, 2.81 mmol) gave a crude product which was purified by flash chromatography eluting with EtOAc to give the *alkene* **56** (41.3 mg, 23%) as an oil, spectroscopically identical to that obtained previously.

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