1,3-Stereocontrol with phosphine oxides: asymmetric synthesis of all four diastereoisomers of a γ′-benzyloxy β-hydroxy phosphine oxide

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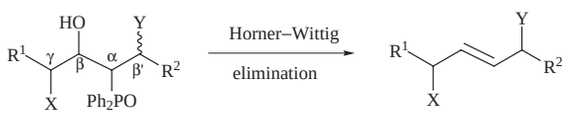
This paper describes how optically active phosphine oxides with a γ′ stereogenic centre [for example, (*R*)-1-diphenylphosphinoylheptan-3-yl benzyl ether] can be lithiated and reacted with aldehydes and esters. The reactions exhibit moderate levels of 1,3 asymmetric induction and models are proposed to explain the stereoselectivity observed in terms of the configurational instability and the known structure of lithiated phosphine oxides. We have developed complementary methods for the asymmetric synthesis of all four diastereomeric β-hydroxy phosphine oxides 4-benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)octan-1-ol and our approach constitutes a formal synthesis of all eight possible stereoisomers. A series of similar β-hydroxy phosphine oxides were eliminated to give optically active homoallylic alcohol derivatives.

Introduction

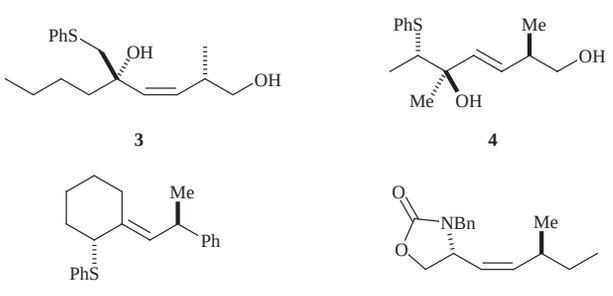
We have established the diphenylphosphinoyl (Ph_2PO) group as a remarkably powerful stereodirecting group in organic synthesis and we have developed many methods for controlling relative stereochemistry using phosphine oxides.[1] In particular, we have used a contiguous chiral centres approach, which is outlined in Scheme 1, in syntheses of racemic and optically



1 **2**

Scheme 1 The contiguous chiral centres strategy.

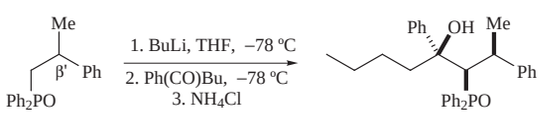
active compounds with 1,4-related stereogenic centres across a double bond of controlled configuration.[2] In each of these syntheses, the diphenylphosphinoyl group was first used to control the relative configuration of four or five contiguous stereogenic centres (as in **1**), two of which (α and β to phosphorus) were subsequently removed in a stereospecific Horner–Wittig elimination (**1**→**2**; Scheme 1).‡ This strategy has been applied to the synthesis of a variety of functionalised compounds, such as the allylic alcohols[3,4] **3** and **4**, the allylic sulfide[5] **5** and alkenyl oxazolidinones[6] such as **6** with 1,4-related stereogenic centres across an alkene.



3 **4**

5 **6**

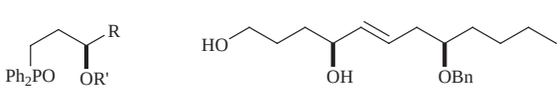
This strategy for remote stereocontrol requires methods which control stereogenic centres on both sides of the diphenylphosphinoyl substituent (see Scheme 1). We have developed many ways to control stereogenic centres α, β and γ to phosphorus[7] but rather fewer methods allow us to control stereogenic centres β′ and γ′ to phosphorus. Recently, we have described how the lithium derivatives of phosphine oxides with a β′ stereogenic centre (*e.g.* **7**) can be reacted with a range of electrophiles; in these reactions, stereogenic centres α, and often also β, to phosphorus can be introduced with high stereoselectivity (→**8**; Scheme 2).[5b] We have rationalised this



7 **8**

Scheme 2

behaviour in terms of the structure[8] and configurational instability[9] of lithiated phosphine oxides. In this paper, we report how the influence of the diphenylphosphinoyl group can be pushed one stage further. Homochiral and racemic phosphine oxides with a stereogenic centre γ′ to phosphorus (of general structure **9**) are used to control the formation of new



9 **10**

stereogenic centres α and β to phosphorus, and in certain cases, it is possible to synthesise *any* of the diastereomeric products at will. The products can be exploited in the synthesis of allylic alcohols (*e.g.* **10**) with 1,5-related stereogenic centres across an *E*-alkene.[10,11]

Results and discussion

Horner–Wittig additions of some prochiral phosphine oxides

As a starting point for our synthetic studies, we compared the reactions of the prochiral phosphine oxides **12**, **14** and **16** to

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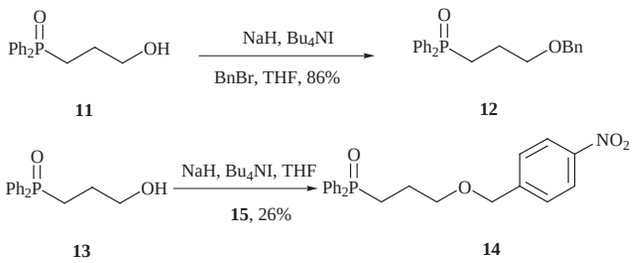
‡ In this paper, all elaborated phosphine oxides are drawn with the hydroxy group which ultimately takes part in the Horner–Wittig elimination to the left of the diphenylphosphine group. The double bond formed by the final Horner–Wittig elimination always joins the α and β carbon atoms; carbon atoms on the other side of the diphenylphosphinoyl group are labelled β′, γ′, *etc*.

Table 1 Horner–Wittig additions of prochiral phosphine oxides to aldehydes (Scheme 4)

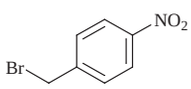
Entry	Starting material	R^1	R^2	Major product	Crude ratio[a,b] **17**:**18** *anti*:*syn*	Yield[c] **17** + **18** (%)
1	**16**	Et	*p*-$MeOC_6H_4$	**17a**	72:28	71 + 26
2	**16**	Et	(*E*)-MeCH=CMe	**17b**	51:49	47 + 45
3	**16**	Et	CH_2=CMe	**17c**	59:41	56 + 34
4	**12**	OBn	*p*-$MeOC_6H_4$	**17d**	80:20	73[d]
5	**12**	OBn	2-furyl	**17e**	82:18	63[d]
6	**12**	OBn	CH_2=CMe	**17f**	82:19	82[d]

[a] By 400 MHz ^{1}H NMR. [b] Stereochemistry assigned using an established coupling constant correlation (ref. 13). [c] Yield of purified diastereomers. [d] Yield of *anti* diastereomer.



11 **12** **13** **14**

Scheme 3



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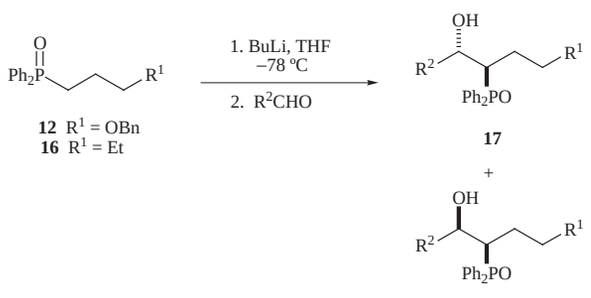
investigate the effect of potentially coordinating substitiuents on the yield and stereoselectivity of Horner–Wittig additions. The syntheses of phosphine oxides **12** and **14** are outlined in Scheme 3.

Phosphine oxides **12** and **16** were treated with a slight excess of butyllithium at −78 °C, and after ten minutes, 1.1 equivalents of freshly distilled aldehyde were added (Scheme 4, Table



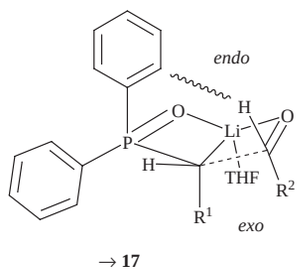
12 R^1 = OBn
16 R^1 = Et

17 + **18**

Scheme 4

1). The reactions of alkyl phosphine oxide **16** were very similar (both in terms of selectivity and yield) to those previously studied.[12] For example, reaction of lithiated **16** with *p*-anisaldehyde gave an excellent (97%) yield of the *anti* β-hydroxy phosphine oxide **17a** and the *syn* β-hydroxy phosphine oxide **18a** in a 3:1 ratio (entry 1, Table 1).§ The stereoselectivity of Horner–Wittig additions has been rationalised in terms of the structure of lithiated phosphine oxides;[8] the aldehyde is thought to displace one of the solvent molecules from the lithium atom of **19**, and rotate into a position in which carbon–carbon bond formation is possible. The transition state leading to the major (*anti*) product, **17**, may resemble a "book" in which both substituents, R^1 and R^2, are on the less hindered *exo* face (Fig. 1). The minor (*syn*) isomer, **18**, presumably forms *via*

§ The relative stereochemistry of the products was determined using an established $^3J_{PH}$ coupling constant correlation (ref. 13).

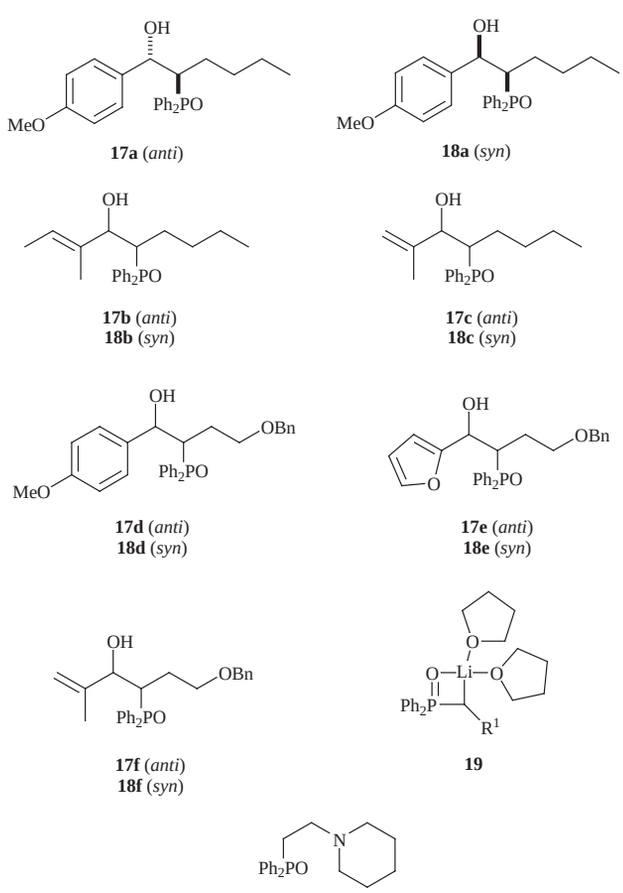


→ **17**

Fig. 1

a similar transition state in which R^1 has flipped into an *endo* position, since the 1,3 diaxial interaction between an *endo* R^2 and one of the phenyl rings on phosphorus would be severe. The reaction of the phosphine oxide **16** with unsaturated aldehydes was, however, virtually stereorandom, giving an almost 1:1 mixture of **17b–c** and **18b–c** (entries 2–3, Table 1). This observation[14] can be explained by suggesting that slim, unsaturated R^2 groups can compete effectively with hydrogen for the rather hindered axial *endo* position (Fig. 1).

The reactions of **12** (with its potentially coordinating benzyl



17a (*anti*) **18a** (*syn*)

17b (*anti*) **18b** (*syn*)

17c (*anti*) **18c** (*syn*)

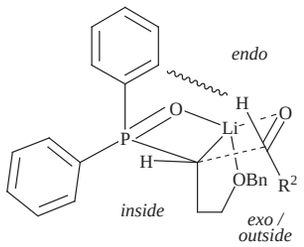
17d (*anti*) **18d** (*syn*)

17e (*anti*) **18e** (*syn*)

17f (*anti*) **18f** (*syn*)

19

20

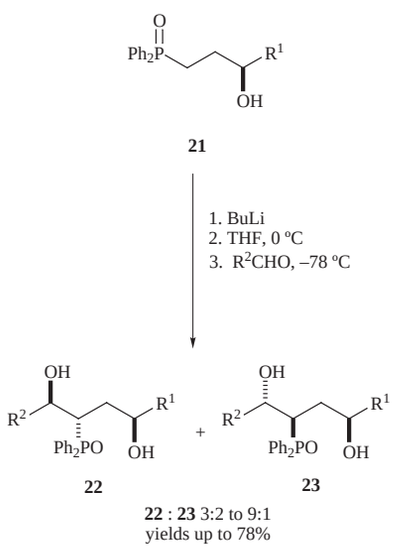


→ **17**

Fig. 2

ether) are remarkable because the stereoselectivities observed are at least as good as those observed with **16** (compare entries 4–6 with entries 1–3, Table 1).¶ In contrast, the nitrogen of amine **20**, with its ability to coordinate lithium, disrupted the usual stereochemical course of the Horner–Wittig reaction.[16] The attempted Horner–Wittig addition of **14** to *p*-anisaldehyde gave, however, only a complex mixture of products.

Our results strongly suggest the formation of a chelate in which the benzyl ether has displaced the second solvent molecule from lithium (Fig. 2). In this structure, the chelating R^1 group is held on the *exo* face of the transition state so the stereoselectivity is eroded only when R^2 flips into an *endo* position. These observations bode well for the reactions of chiral versions of **12** (of general structure **9**) since a substituent next to the chelating benzyl ether may have a profound preference for the "inside" or the "outside" face of the chelate.



Scheme 5

¶ For the effect of a β-oxido substituent on the stereoselectivity of the Horner–Wittig addition, see ref. 15.

Horner–Wittig additions of chiral phosphine oxides with a γ′ stereogenic centre

Recently, Okuma described the addition of dilithiated γ′-hydroxy phosphine oxides **21** with aldehydes (Scheme 5).[17] In this study, optically active phosphine oxides **21**, which had been classically resolved, were dilithiated and were found to react diastereoselectively with aldehydes, giving diols **22** and **23** in good yield and with good 1,3-stereoselectivity.

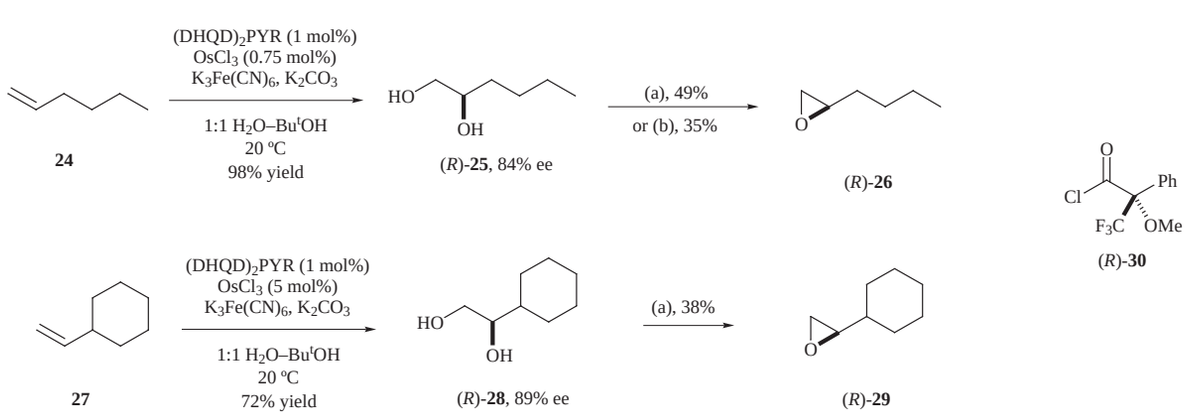
We synthesised the optically active diols (*R*)-**25** and (*R*)-**28** by asymmetric dihydroxylation of the alkenes **24** and **27** using the conditions and ligand recommended by Sharpless (Scheme 6).[18] The enantiomeric excesses of the diols **25** and **28** were determined by derivatisition with Mosher's acid chloride (*R*)-**30**.[19] The optically active epoxides (*R*)-**26** and (*R*)-**29** were synthesised from the diols **25** and **28** using the stereospecific sequence of reactions introduced by Sharpless.[20] The epoxides **26**, **29**, **33** and **34** were opened with the lithium derivative of

33 **34**

methyldiphenylphosphine oxide and the alcohols **21** obtained were protected using standard conditions (Scheme 7). We have previously synthesised optically active alcohols **21** by reduction of γ-hydroxy vinyl phosphine oxides.[21]

We studied the Horner–Wittig reactions of protected versions of the γ′-hydroxy phosphine oxides **21**. Our aim was simple: to find out which pairs of phosphine oxides and aldehydes reacted stereoselectively, giving β-hydroxy phosphine oxides **35**–**38** in reasonable yield; the crude ratio of products was determined in each case by 400 MHz ^{1}H NMR spectroscopy, and the mixtures of *anti* β-hydroxy phosphine oxides **35** and **36** were separated from the *syn* isomers **37** and **38** by flash chromatography. The results of this study are presented in Scheme 8 and Table 2.

We found that the yield and stereoselectivity of our reactions were best with aromatic aldehydes (compare entries 1–4 with entries 5–7, Table 2). In these cases, we were able to isolate good yields (60–82%) of mixtures of *anti* β-hydroxy phosphine oxides **35** and **36**. Furthermore, there was some control (between 2:1 to 3:1) over the 1,3 relationship between the chiral centres α and γ′ to phosphorus. In each case, the relative stereochemistry across the new carbon–carbon bond was assigned using an established $^3J_{PH}$ coupling constant correlation.[13] The geminal coupling constants between the benzylic protons of benzyl ethers **35**–**38** (of general structure **39**) were found to depend remarkably on the relative stereochemistry of the 1,3-related stereogenic centres (Table 3); the major products

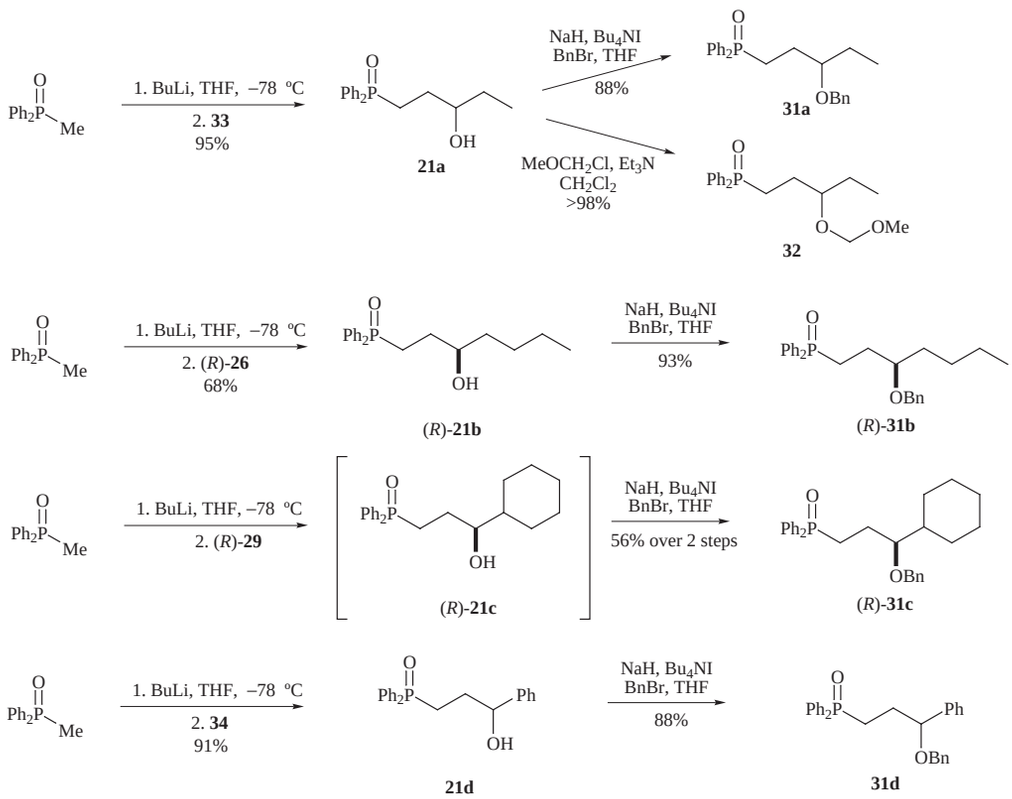


Scheme 6 *Reagents and conditions*: (a) (i) $(MeO)_3CMe$, PPTS, CH_2Cl_2; (ii) AcBr, CH_2Cl_2; (iii) K_2CO_3, MeOH; (b) (1) $(MeO)_3CMe$, PPTS, CH_2Cl_2; (ii) AcBr, CH_2Cl_2; (iii) KOH, MeOH, ether; (iv) distill.

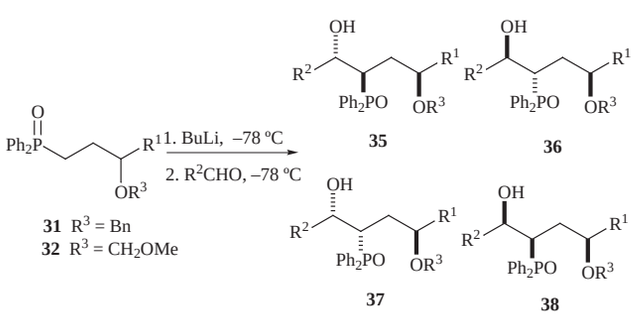
Table 2 Horner–Wittig additions of chiral phosphine oxides to aldehydes in THF (Scheme 8)

Entry	Starting material	R^1	R^2	R^3	Major product	Crude ratio [a,b] **35**:**36**:**37**:**38**	Yield [c] **35** + **36** (%)	Ratio [a] **35**:**36**	Yield [d] **35** (%)	Yield [d] **36** (%)
1	**31a**	Et	2-furyl	Bn	**35a**	73:18:5:5	64	78:22	36	9 [e]
2	**31b**	Bu	2-furyl	Bn	**35b**	75:25:0:0	61	82:18	23	18
3	**31c**	C_6H_{11} [f]	2-furyl	Bn	**35c**	70:21:9:0	82	78:22	—	—
4	**31b**	Bu	*p*-$MeOC_6H_4$	Bn	**35d**	62:38:0:0	60	61:39	33	5
5	**31a**	Et	*p*-MeCH=CMe	Bn	**35e**	[g]	35	60:40	—	—
6	**31a**	Et	CH_2=CMe	Bn	**35f**	[g]	19	62:38	—	—
7	**32**	Et	CH_2=CMe	CH_2OMe	**35g**	42:32:16:0	38	55:45	—	—

[a] By 400 MHz ^{1}H NMR. [b] *Anti*:*syn* stereochemistry (**35** + **36**:**37** + **38**) across the new carbon–carbon bond assigned using an established $^3J_{PH}$ coupling constant correlation (ref. 13). [c] Yield of mixture after flash chromatography. [d] Yield of purified isomer after preparative HPLC. [e] 85:15 mixture of **36a**:**35a**. [f] Cyclohexyl. [g] Not measured; all four diastereoisomers present.



Scheme 7



Scheme 8

of each of the addition reactions in THF (Table 2) had $^2J_{HH} \approx 12.0$ Hz, suggesting that the sense of the 1,3-induction was the same in each case. The relative stereochemistry of the products was determined by conversion of the alcohol **35b** into a product (**10**) of known stereochemistry.[11] We were able to separate the ^{1,3}*anti* alcohols **35a**–**b** and **35d** from the ^{1,3}*syn* alcohols **36a**–**b** and **36d** by preparative HPLC.

The reactions of benzyl ether **31a** with unsaturated aldehydes were much less encouraging (entries 5–6, Table 2). The isolated yields of the products were poor, and were accompanied by significant quantities of *syn* products **37e**–**f** and **38e**–**f**. On moving from aromatic to unsaturated aldehydes, the control over the relative stereochemistry across the new carbon–carbon bond was eroded from at least 90:10 to about 70:30. The control over the more remote (1,3) chiral relationship was worse as well. We tried to improve the situation by studying the addition of the MOM acetal **32** to methacrolein, but the yield and stereoselectivity were broadly the same (compare entry 7 with entries 5–6, Table 2).

Our analysis of the stereoselectivity of these Horner–Wittig additions is broadly similar to that of the reactions of phosphine oxide **12** (see Fig. 2), but with the added complication of the chiral centre already present in phosphine oxides **31**. We explain the high *anti* selectivity of these reactions in the same way as before: the chelating benzyl ether is held on the *exo* face of the "book-like" transition states **41** and **42**, so provided that R^2 is reasonably large (and forced to be on the *exo* face), high *anti* stereoselectivity is assured (Scheme 9). When the size of R^2 is decreased, it can compete with hydrogen for one of the more hindered *endo* positions, lowering the *anti* selectivity of the reaction.

The high *anti* selectivity of the additions to aromatic aldehydes (entries 1–4, Table 2) has allowed us to analyse some of

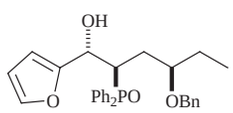
Table 3 Geminal coupling constant between benzylic protons in benzyl ethers **35**–**38**

Compound	R^1	R^2	**35** $^2J_{AB}$/Hz	**36** $^2J_{AB}$/Hz	**37** $^2J_{AB}$/Hz	**38** $^2J_{AB}$/Hz
35–**38a**	Et	2-furanyl	12.1	11.0	—	—
35–**38b**	Bu	2-furanyl	12.1	10.9	11.0	12.0
35–**38c**	C_6H_{11} [a]	2-furanyl	12.2	10.9	11.0	12.1
35–**38d**	Bu	*p*-$MeOC_6H_4$	12.1	11.1	11.1	11.8
35–**38h**	Et	Ph	12.1	11.1	—	—
35–**38i**	Bu	Ph	—	—	11.1	11.9
35–**38j**	Ph	Ph	11.9	11.0	11.0	11.6
	maximum value		12.2	11.1	11.1	12.1
	minimum value		11.9	10.9	11.0	11.6

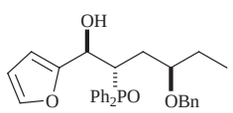
[a] Cyclohexyl.

the factors which underlie the 1,3 stereocontrol observed. To a first approximation, the only populated transition states are **41** and **42**. Lithiated phosphine oxides are configurationally unstable,[9] even on the timescale of their reaction with aldehydes, so all of the material can choose which pathway is followed. The R^1 side chain of phosphine oxides **31** has an approximately 3 : 1 preference for the "outside" position of **41** over the "inside" position of chelated structure **42**, which translates into an approximately 3 : 1 ratio of products **35** and **36**.

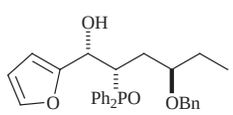
We also investigated the effect of solvent on the stereoselectivity of our Horner–Wittig additions and the results of this study are presented in Scheme 8 and Table 4. The effect of DME on the reaction of the phosphine oxide **31a** with furfural was broadly the same as that of THF, though the reaction was marginally less *anti* selective (compare entry 1, Table 4 with entry 1, Table 2).‖



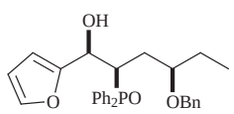
35a



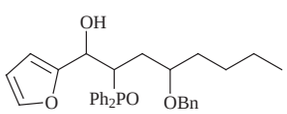
36a



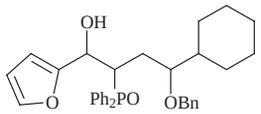
37a



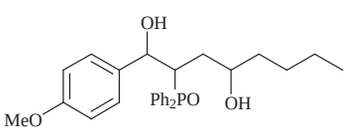
38a



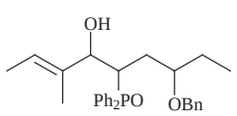
35–38b



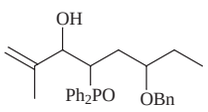
35–38c



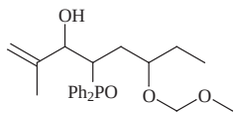
35–38d



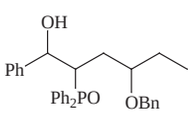
35–38e



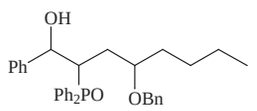
35–38f



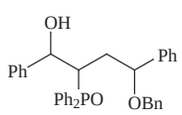
35–38g



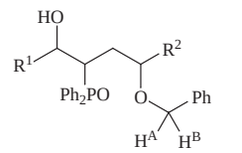
35–38h



35–38i



35–38j



39

The reversal in stereoselectivity is difficult to explain, but one possibility is that the aggregation state of our lithiated phosphine oxide reagents has changed on moving from THF to toluene. Coordination of lithium by THF tends to break-up organolithiums aggregates, so perhaps the reactive species in toluene is a dimer like **43**.[24] The change in solvent lowers the magnitude of, and reverses the sense of the 1,3-stereocontrol.

The effect of toluene, a less coordinating solvent, was studied in the hope that this would promote chelation control and increase the diastereoselectivity of the reactions.[23] The crude reaction mixtures were analysed by ^{1}H NMR and the two *anti* diastereomers (**35** and **36**) were isolated by flash chromatography. On moving from THF to toluene, we found that the *anti* selectivity of the Horner–Wittig additions was lowered considerably (entries 2–5, Table 4 and Scheme 8).** For example, the reactions of **31a**–**b** with aromatic aldehydes (entries 3–5, Table 4) produced significant quantities (up to 25% of the crude reaction mixture) of the two *syn* diastereomers **37** and **38**, but these isomers were not observed when the reaction was performed in THF. As before, an addition to an unsaturated aldehydes was even less selective (entry 2, Table 4).

There was, however, one very positive side to these results; the control over the 1,3-related chiral centres had been reversed. The ratio of the two *anti* diastereomers had been changed from a good selectivity (between 3 : 1 and 4 : 1) in favour of the ^{1,3}*syn* alcohol **35** to a modest preference (up to 2 : 1) for the ^{1,3}*anti* diastereomer **36**.†† The yields for the isolated *anti* isomers were rather low, partly because the addition was less *anti* selective than in THF, but we were pleased to have developed a complementary route to the ^{1,3}*anti* isomer **36**.

Stereoselective acylation and reduction of chiral phosphine oxides with a γ′ stereogenic centre

The diastereoselective acylation of chiral phosphine oxides **31** was much easier to study than the corresponding Horner–Wittig additions because the reaction leads to the formation of only one new stereogenic centre.[25] The acylation of phosphine oxides **31** gave good yields of β-keto phosphine oxides **44** and **45** with moderate levels of 1,3-stereocontrol (Scheme 10 and Table 5). The ketones **44** and **45** were rather susceptible to

‖ DME can have a remarkable effect on the yield of some organolithium reactions (ref. 22).

** We have previously noted that Horner–Wittig additions are less *anti* selective in toluene than in THF (ref. 12).

†† We use the stereochemical designator ^{1,3}*syn* to indicate that functional groups attached to two carbons with a 1,3-relationship are both above or both below the plane of the illustration. Similarly, the designator ^{1,3}*anti* indicates that the 1,3-related functional groups are on opposite sides of the illustration.

Table 4 Effect of solvent on the stereoselectivity of Horner–Wittig additions of chiral phosphine oxides (Scheme 8)

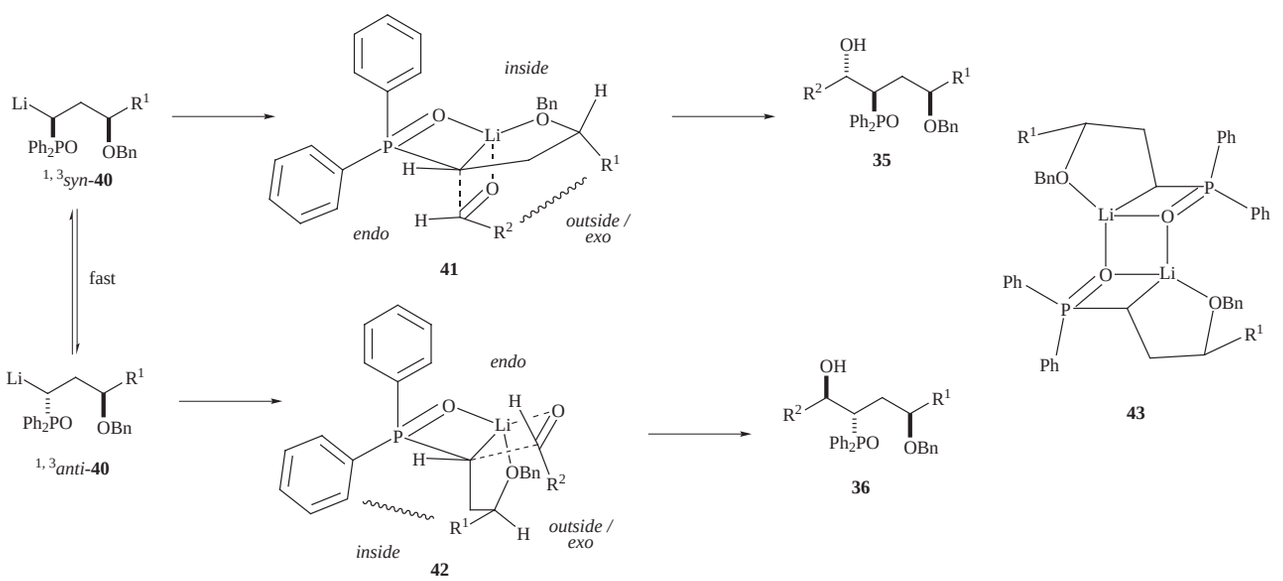
Entry	Starting material	R^1	R^2	Solvent	Major product	Crude ratio [a,b] **35**:**36**:**37**:**38**	Yield [c] **35** + **36** (%)	Ratio [a] **35**:**36**
1	**31a**	Et	2-furyl	DME	**35a**	57:19:11:13	46	77:23
2	**31a**	Et	CH_2=CMe	toluene	**36f**	17:39:20:25	33	29:71
3	**31a**	Et	Ph	toluene	**36h**	25:51:19:6	38	34:66
4	**31b**	Bu	2-furyl	toluene	**36d**	34:43:25:0	56	43:57
5	**31b**	Bu	*p*-$MeOC_6H_4$	toluene	**36b**	[d]	33	44:56

[a] 400 MHz ^{1}H NMR. [b] *Anti*:*syn* stereochemistry (**35** + **36**:**37** + **38**) across the new carbon–carbon bond assigned using an established $^3J_{PH}$ coupling constant correlation (ref. 13). [c] Yield of mixture after flash chromatography. [d] Not measured.

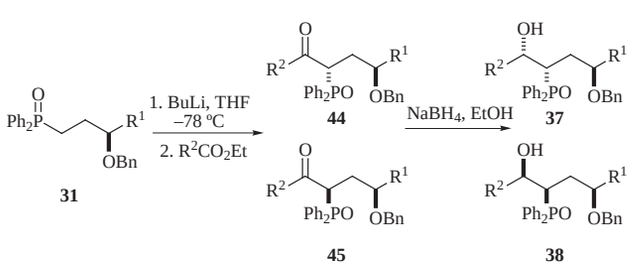
Table 5 Stereoselective acylation and reduction of chiral phosphine oxides (Scheme 10)

				Acylation			Reduction				
Entry	Starting material	R^1	R^2	Crude ratio [a] **44**:**45**	Yield [b] **44** + **45** (%)	Ratio [a] **44**:**45**	Major product	Yield [b] **37** + **38** (%)	Ratio **37**:**38**	Yield [c] **37** (%)	Yield [c] **38** (%)
1	**31b**	Bu	2-furyl	72:28	60	63:37	**37b**	97	63:37	76	21
2	**31b**	Bu	Ph	[d]	74	65:35	**37i**	46	70:30	—	—
3	**31c**	C_6H_{11} [e]	2-furyl	67:33	60	69:31	**37c**	71	71:29	—	—
4	**31d**	Ph	Ph	79:31	82	80:20	**37j**	93	72:28	—	—

[a] By 400 MHz ^{1}H NMR. [b] Yield of mixture after flash chromatography. [c] Yield of purified isomer after preparative HPLC. [d] Not measured; all diastereoisomers present. [e] Cyclohexyl.



Scheme 9



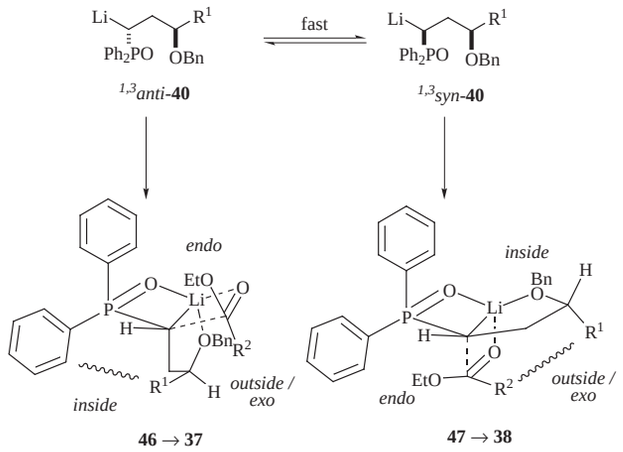
Scheme 10

epimerisation and therefore we chose to convert the mixtures of products directly into the *syn* β-hydroxy phosphine oxides **37** and **38**.[12] Remarkably, and in contrast to the corresponding additions to aldehydes in THF (Table 2), the acylation of phosphine oxides **31** was found to be ^{1,3}*anti* selective. Once again, the 1,3-stereochemistry of the alcohols **37** and **37** could be determined using the coupling constant correlation described in Table 3.

The most likely explanation for the reversed 1,3 stereocontrol (on moving from the reactions of aldehydes to those of ketones) is quite simply that the diastereomeric lithium derivative ^{1,3}*anti*-**40** is the more reactive diastereomer in acylation reactions (Scheme 11).‡‡ Once again, the configurational instability of lithiated phosphine oxides is central to the outcome of the reaction; both transition states **46** and **47** are accessible to the rapidly interconverting mixture of organolithiums ^{1,3}*syn*- and ^{1,3}*anti*-**40**.

Our results are rather similar to, though less impressive than, some allylation reactions reported by Beak.[26] In these experiments, a pair of rapidly interconverting organolithium reagents, which were diastereomeric by virtue of coordination

‡‡ We have assumed that the S_E2 reactions of the lithiated phosphine oxides with carbonyl electrophiles proceed with retention of configuration. This is reasonable in the light of recent evidence (ref. 8) that aldehydes precoordinate to the lithium atom, ensuring a 90° angle between the old (C–Li) and new (C–C) bonds.



Scheme 11

by (−)-sparteine reacted with allyl chloride and allyl tosylate to give enantiomeric products; the configurational instability of the intermediate organolithiums was necessary for these dynamic kinetic resolutions.[27]

Preparation of β-hydroxy phosphine oxides by oxidation–stereoselective reduction

We have described stereoselective routes to three (**35**, **36** and **37**) of the four diastereomers of a β-hydroxy phosphine oxide and we needed to develop a complementary route to the remaining isomers **38**. An approach which involves the oxidation of the *anti* alcohols (**35** or **36**) with Dess–Martin's periodinane§§ **48** to the corresponding ketones (**45** or **44**), and *syn*-selective reduction[12] with sodium borohydride (→**38** or **37**) is presented in Scheme 12 and Table 6. The remote stereogenic centre in these molecules acts as handle for determining whether the intermediate ketones epimerised under the reaction conditions; in two cases (entries 1 and 2, Table 6), we analysed the crude reaction mixture after oxidation with Dess–Martin's reagent and were pleased to find that no enolisation had occurred.¶¶ This approach also allowed us to correlate the stereochemistry of *anti* β-hydroxy phosphine oxides **35** and **36** with *syn* β-hydroxy phosphine oxides **37** and **38**.

The intermediate crude β-keto phosphine oxides (**44** or **45**) were treated with a large excess of sodium borohydride; unfortunately, epimerisation of the intermediate β-keto phosphine oxides occurred when the reaction was performed on a large scale (compare entry 1 with entry 2, Table 6). Epimerisation of β-keto phosphine oxide has previously been observed under Luche's reduction conditions (sodium borohydride with added cerium trichloride).[25] We were able to solve this problem by cooling the reaction mixture to 0 °C and adding the sodium borohydride in small portions over 30 minutes. In this way, epimerisation was often avoided altogether (entries 2 and 4, Table 6). Even when the reaction was performed on a larger scale (entry 3b, Table 6), the relative stereochemistry of the 1,3-related stereogenic centres remained largely intact, and in this case, we were able to separate the *syn* isomers of **37b** and **38b** by preparative HPLC.

Synthesis of optically active *E* and *Z* protected homoallylic alcohols

We have already explained that the Horner–Wittig additions of phosphine oxides **31** to aromatic aldehydes were almost completely *anti* selective across the new carbon–carbon bond, and that mixtures of *anti* isomers **35** and **36** were readily isolated by flash chromatography. Mixtures of *anti* β-hydroxy phosphine oxides **35** and **36** were added to a suspension of sodium hydride in DMF, and after work-up, alkenes (*Z*)-**49** were isolated in reasonable yield (Scheme 13). Attempted Horner–Wittig elimination of a mixture of **35b** and **36b** using generally more reliable conditions (KOH in DMSO) was not successful; none of the required alkene (*Z*)-**49a** was observed in the ^{1}H NMR spectrum of the crude reaction mixture.

We were pleased to find that these Horner–Wittig eliminations were completely stereospecific: none of the thermodynamically favoured (*E*) isomers were observed. This result was perhaps surprising, since elimination of a mixture of **36d** and **35b** gave a poor 30% yield of alkene (*Z*)-**49b** accompanied by a 23% yield of *p*-anisaldehyde, indicating that the reverse Horner–Wittig addition was a competing side-reaction. This process has been proposed to explain the stereochemical "leakage" of many Horner–Wittig eliminations.[31]

Similarly, mixtures of the *syn* β-hydroxy phosphine oxides **37** and **38** were eliminated under the same reaction conditions to yield the corresponding *E*-alkenes (*E*)-**49** (Scheme 14). In fact, the synthetic route described in Schemes 13 and 14 outlines the formal synthesis of all four stereoisomers of these homoallylic alcohol derivatives since the enantiomeric benzyl ethers could have been synthesised simply by using a different ligand in the AD reaction used to introduce the asymmetry. Previously, racemic homoallylic alcohol derivatives (similar to **49**) have been made (as *E* and *Z* mixtures) using the Wittig[32] and Julia[33] olefination reactions and (as single compounds) using a palladium-catalysed coupling reaction.[34] Okuma has prepared optically active homoallylic alcohols using phosphine oxide chemistry.[17]

We briefly looked at the possibility of developing a stereoselective route to trisubstituted alkenes. To this end, we added the lithiated secondary phosphine oxide **51** to benzaldehyde (Scheme 15) but we isolated a mixture of all four diastereomers of β-hydroxy phosphine oxide **52**. Nevertheless, elimination of this mixture gave a 64 : 36 mixture of trisubstituted alkenes **53**, indicating that there had been some asymmetric induction across the new carbon–carbon bond in the addition step.

Summary

In this paper, we have described complementary routes to all four diastereomeric alcohols **35b**, **36b**, **37b** and **38b** from the same phosphine oxide **31b**. These reaction sequences are summarised in Scheme 16. *Anti* β-hydroxy phosphine oxides (**35** and **36**) were synthesised by adding the lithium derivative of a phosphine oxide (*e.g.* **31b**) to an aldehyde; it was possible to control the 1,3 chiral relationship in these molecules by careful choice of solvent. The stereoselectivities of these addition reactions in THF and toluene are at their best (and oppose one another) when aromatic aldehydes (like furfural) are used.

Alternatively, reduction of β-keto phosphine oxides **44** and **45** with sodium borohydride was highly *syn* selective, and allowed the synthesis of *syn* β-hydroxy phosphine oxides **37** and **38**. In this way, ketones **44** (synthesised by oxidation of alcohols **35**) and **45** (obtained by acylation of phosphine oxides **31**) were reduced to give the *syn* diastereomers of **38** and **37**. The success of our complementary routes hinges on the configurational instability of lithiated phosphine oxides; access to ^{1,3}*syn* and ^{1,3}*anti* diastereomeric series was possible because aldehydes and esters reacted preferentially with different isomers of a rapidly equilibrating mixture of lithiated phosphine oxides **40** (Schemes 9 and 11).

In fact, our synthesis of the four diasteromers **35b**, **36b**, **37b** and **38b** constitutes a formal synthesis of all eight stereoisomers; the other enantiomeric series could have been accessed simply by choosing a different alkaloid ligand in the asymmetric dihydroxylation reaction used to synthesise benzyl ether

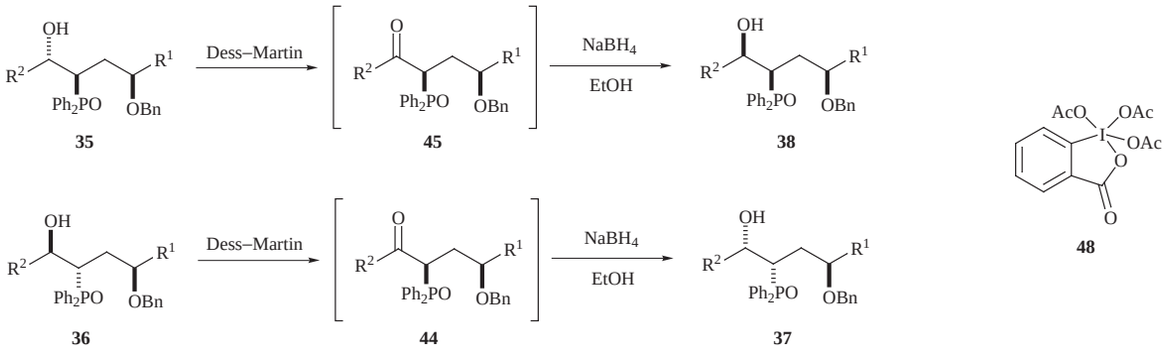
§§ Dess–Martin's periodinane (ref. 28) is the best (ref. 29) reagent for the preparation of base-sensitive ketones.

¶¶ Previous workers have not been faced by the problem of epimerisation of β-keto phosphine oxides and have simply used chromium reagents in the oxidation step (ref. 30).

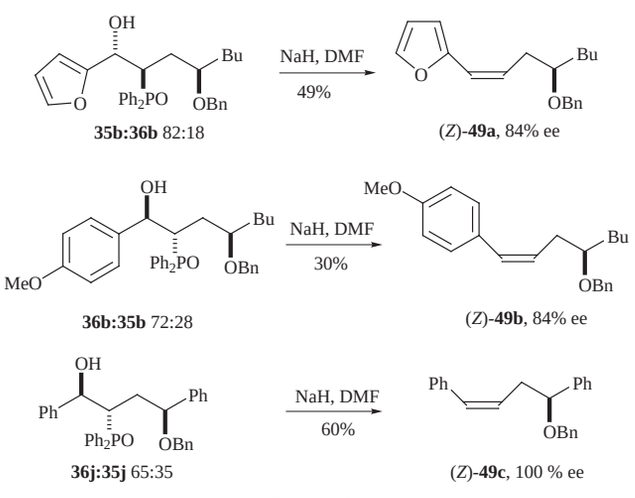
Table 6 Oxidation and stereoselective reduction of β-hydroxy phosphine oxides (Scheme 12)

Entry	Starting material	R^1	R^2	Starting mixture **35**:**36**	Oxidation product ratio[a] **45**:**44**	Reduction *T*/°C	Major product	Yield over 2 steps[b] **38** + **37** (%)	Ratio **38**:**37**	Yield[c] **38** (%)
1[d]	**35d**	Bu	*p*-$MeOC_6H_4$	>95:5	>95:5	20	**38d**	69	51:49	[e]
2	**31b**	Bu	*p*-$MeOC_6H_4$	15:85	15:85	0	**37b**	83	13:87	[e]
3a[f]	**31c**	Bu	2-furyl	>95:5	[g]	20	**38b**	83	>95:5	[e]
3b[h]	**35b**	Bu	2-furyl	>95:5	[g]	0	**38b**	80	81:19	53
4	**31d**	C_6H_{11}[i]	2-furyl	78:22	[g]	0	**38c**	90	75:25	[e]

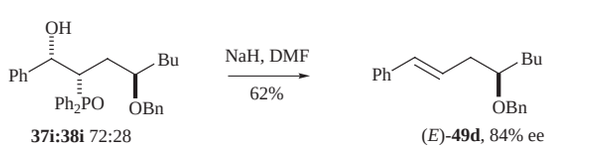
[a] By 400 MHz ^{1}H NMR. [b] Yield of mixture after flash chromatography. [c] Yield of purified isomer after preparative HPLC. [d] Reaction on a 1.1 g scale. [e] Not purified by preparative HPLC. [f] Reaction on a 80 mg scale. [g] Not measured. [h] Reaction on a 600 mg scale. [i] Cyclohexyl.

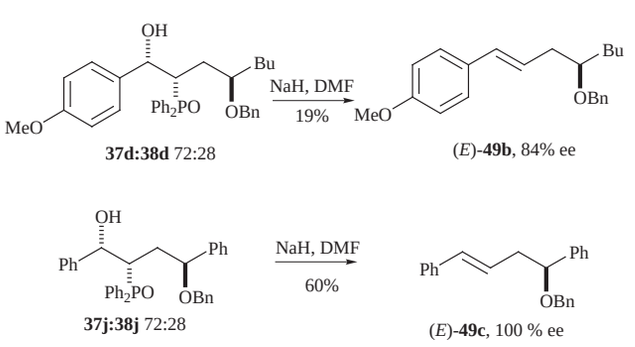


Scheme 12

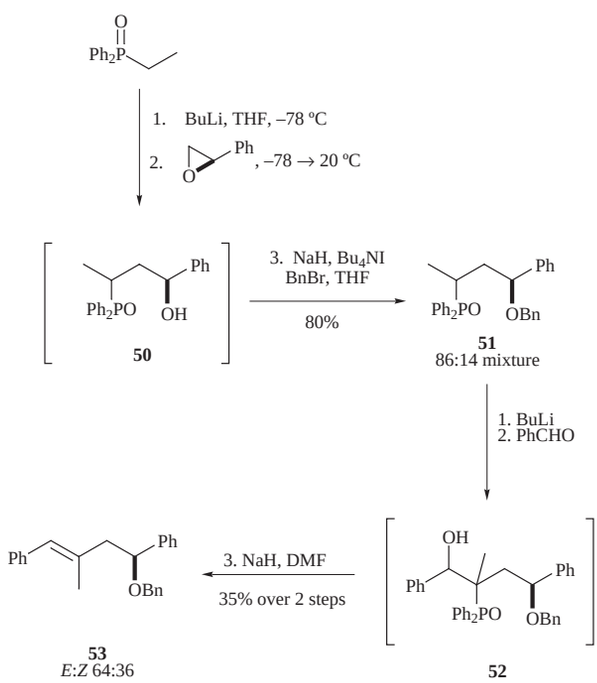


Scheme 13





Scheme 14

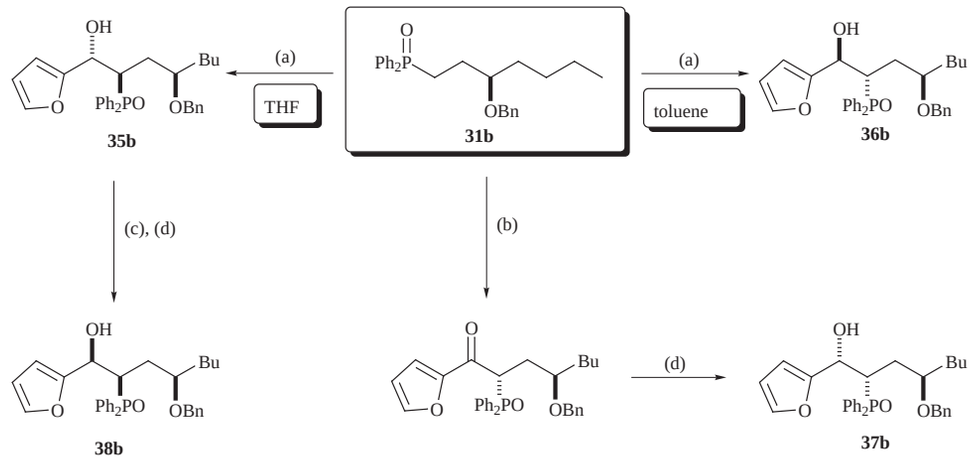


Scheme 15

31b. The β-hydroxy phosphine oxides were valuable intermediates in the synthesis of optically active homoallylic alcohol derivatives **49**.

Experimental

All solvents were distilled before use. THF and Et_2O were freshly distilled from lithium aluminium hydride whilst CH_2Cl_2 and toluene were freshly distilled from calcium hydride. Triphenylmethane was used as indicator for THF. *n*-Butyllithium was titrated against diphenylacetic acid before use. All non-aqueous reactions were carried out under argon using oven-dried glassware.



Scheme 16 *Reagents and conditions*: (a) (i) BuLi; (ii) furfural; (b) (i) BuLi, THF; (ii) ethyl 2-furoate; (c) Dess–Martin periodinane; (d) $NaBH_4$, EtOH.

Flash column chromatography was carried out using Merck Kieselgel 60 (230–400 mesh) according to the method of Still, Kahn and Mitra.[35] Thin layer chromatography was carried out on commercially available pre-coated plates (Merck silica Kieselgel $60F_{254}$). Proton and carbon NMR spectra were recorded on Bruker WM 200, WM 250, WM 400 or AMX 500 Fourier transform spectrometers using an internal deuterium lock. Chemical shifts are quoted in parts per million downfield of tetramethylsilane and values of coupling constants (*J*) are given in Hz. The presence of an asterisk (*) after the proton NMR chemical shift indicates that the signal disappears after a D_2O "shake". 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.

Melting points were measured on a Reichart hot stage microscope or a Buchi 510 melting point apparatus and are uncorrected. Infra red spectra were recorded on a Perkin-Elmer 1600 (FT-IR) spectrophotometer. Mass spectra were recorded on a Kratos double-beam mass spectrometer using a DS503 data system for high resolution analysis. Electron Impact was used unless Fast Atom Bombardment (+FAB) is indicated. Microanalyses were carried out by the staff of the University Chemical Laboratory using Carlo Erba 1106 or Perkin-Elmer 240 automatic analysers. Optical rotations were recorded on a Perkin-Elmer 241 polarimeter (using the sodium D line; 589 nm) and $[a]_D^{20}$ are given in units of 10^{-1} deg cm^2 g^{-1}. (*R*)-Pirkle's reagent is (*R*)-(−)-2,2,2-trifluoro-1-(9-anthryl)ethanol.

(*R*)-Hexane-1,2-diol 25

By the method of Sharpless,[36] hydroquinidine 2,5-diphenyl-pyrimidine-4,6-diyl diether [$(DHQD)_2PYR$] (1.63 g, 1.83 mmol), potassium carbonate (83.5 g, 605 mmol), potassium ferricyanide (192 g, 605 mmol) and osmium trichloride (500 mg, 1.59 mmol) were stirred in 1 : 1 ^{t}BuOH–water (20 cm^3) at 25 °C. The solution was cooled to 0 °C whereupon some of the dissolved salts precipitated. Hex-1-ene (17.0 g, 202 mmol) was immediately added. The slurry was stirred vigorously for 3 days. Sodium sulfite (291 g, 3.1 mol) was added, the temperature allowed to warm to 20 °C and the slurry stirred for a further 30 min. EtOAc (1000 cm^3) was added to the reaction mixture, and the aqueous fraction extracted with EtOAc (3 × 1000 cm^3), washed with water (1000 cm^3) and brine (1000 cm^3), dried ($MgSO_4$) and evaporation gave a crude product. Flash chromatography, and eluting with Et_2O, gave the diol[37] **25** (22.55 g, 98%) as a liquid, $[a]_D^{20}$ +7.51 (*c* 2.5 in Et_2O) (lit.[37] +15.2, neat); ν_{max}/cm^{-1} ($CHCl_3$) 3475 (OH); δ_H (400 MHz; $CDCl_3$) 3.67 (1 H, m, C*H*OH), 3.62 (1 H, dd, *J* 2.9 and $^2J_{HH}$ 11.1, CH_AH_BOH), 3.41 (1 H, dd, *J* 6.6 and $^2J_{HH}$ 11.0, CH_AH_BOH), 1.45–1.25 (6H, m) and 0.88 (3 H, t, *J* 7.1, Me); δ_C (50 MHz; $CDCl_3$) 72.3$^+$ (CHOH), 66.7$^-$ (CH_2OH), 32.8$^-$, 27.7$^-$, 22.6$^-$ and 14.0$^+$ (Me). Integration of the 500 MHz ^{1}H NMR spectrum of the Mosher's diesters of this material showed it to have 84% ee.

(*R*)-1-Cyclohexylethane-1,2-diol 28

By the same general method, vinylcyclohexane (6.2 cm^3, 45.5 mmol), $(DHQD)_2PYR$ (465 mg, 0.53 mmol), potassium carbonate (21.7 g, 157 mmol), potassium ferricyanide (50.0 g, 152 mmol) and osmium trichloride (300 mg, 2.22 mmol) gave a crude product after stirring for 3 days with a mechanical stirrer. Flash chromatography, eluting with Et_2O, gave the diol[36] **28** (4.73 g, 72%) as a liquid, $[a]_D^{20}$ −2.0 (*c* 0.64 in $CHCl_3$) (lit.[36] −4.17, *c* 1.73 in $CHCl_3$) (Found: M$^+$ − OH, 127.1125. $C_8H_{16}O_2$ requires *M* − *OH*, 127.1122); ν_{max}/cm^{-1} ($CHCl_3$) 3413 (OH); δ_H (400 MHz; $CDCl_3$) 3.65 (1 H, m, C*H*OH), 3.62 (1 H, dd, *J* 2.9 and $^2J_{HH}$ 11.1, CH_AH_BOH), 3.41 (1 H, dd, *J* 6.6 and $^2J_{HH}$ 11.1, CH_AH_BOH), 2.20–1.10 (11 H, m) and 0.88 (3 H, t, *J* 7.1, Me); *m*/*z* 127.1 (18%, M − OH) and 95.1 (100). Integration of the 500 MHz ^{1}H NMR spectrum of the Mosher's diesters of this material showed it to have 89% ee.

(*R*)-Butyloxirane 26

By the method of Sharpless,[20] trimethyl orthoacetate (864 mg, 6.5 mmol) was added dropwise to a solution of the diol **25** (780 mg, 6.0 mmol) and pyridinium toluene-*p*-sulfonate (16 mg, 65 μmol) in dry dichloromethane (10 cm^3). After stirring for 15 min, the reaction mixture was evaporated to dryness and the vessel evacuated on a trolley pump for 2 min. The reaction mixture was dissolved in dry dichloromethane (10 cm^3) and acetyl bromide (885 mg, 7.2 mmol) was added dropwise at 0 °C. The reaction mixture was warmed to 20 °C, stirred for 30 min and evaporated under reduced pressure. Potassium carbonate (1.43 g, 10.4 mmol) and methanol (20 cm^3) were added, and the reaction was stirred for 75 min. The reaction was quenched with water (10 cm^3), extracted with Et_2O (3 × 10 cm^3) and evaporated under reduced pressure (with no heat) to give a crude product. Distillation from $MgSO_4$ (bp 117–119 °C, lit.[38] 118–129 °C) gave the epoxide[38] **26** (330 mg, 49%) as a liquid, $[a]_D^{20}$ +13.7 (*c* 1.34 in Et_2O; 84% ee); ν_{max}/cm^{-1} ($CHCl_3$) no characteristic peaks; δ_H (400 MHz; $CDCl_3$) 2.81 (1 H, m, C*H*O), 2.65 (1 H, app. t, *J* 4.5, CH_AH_BO), 2.36 (1 H, dd, *J* 2.7 and 5.1, CH_AH_BO), 1.5–1.25 (6 H, m) and 0.82 (3 H, t, *J* 7.1, Me); δ_C (50 MHz; $CDCl_3$) 52.4$^+$ (CHO), 47.1$^-$ (CH_2O), 32.2$^-$, 28.1$^-$, 22.5$^-$ and 14.0$^+$ (Me).

(*R*)-Cyclohexyloxirane 29

By the same general method, trimethyl orthoacetate (4.78 cm^3, 37.4 mmol), (*R*)-cyclohexylethane-1,2-diol (4.62 g, 32.1 mmol),

pyridinium toluene-*p*-sulfonate, acetyl bromide (2.8 cm^3, 37.5 mmol) and potassium carbonate (7.6 g, 55.1 mmol) gave a crude product which was stored over freshly activated molecular sieves to give the epoxide[39] **29** (1.52 g, 38%) as a liquid, $[\alpha]_D^{20}$ −2.0 (neat; 89% ee) (lit.[39] +2.1 for *S* isomer, neat); ν_{max}/cm^{-1} ($CHCl_3$) no characteristic peaks; δ_H (400 MHz; $CDCl_3$) 2.71 (2 H, m), 2.51 (1 H, t, *J* 4.2, CH_AH_BO), 1.85 (1H, m), 1.8–1.6 (4 H, m) and 1.3–1.0 (6 H, m); δ_C (50 MHz; $CDCl_3$) 56.7$^+$ (CHO), 46.0$^-$ (CH_2O), 29.7$^-$, 28.8$^-$, 26.3$^-$, 25.7$^-$ and 25.5$^-$.

(*R*)-Butyloxirane 26

By the method of Sharpless,[20] trimethyl orthoacetate (2.56 cm^3, 20.1 mmol) was added dropwise to a solution of (*R*)-hexane-1,2-diol (1.99 g, 16.9 mmol) and pyridinium toluene-*p*-sulfonate (45 mg, 0.19 mmol) in dry dichloromethane (15 cm^3).[18] After stirring for 15 min, the reaction mixture was evaporated to dryness and the vessel evacuated on a trolley pump for 2 min. The reaction mixture was dissolved in dry dichloromethane (15 cm^3) and acetyl bromide (1.45 cm^3, 19.6 mmol) was added dropwise at 0 °C. The reaction mixture was warmed to 20 °C, stirred for 30 min, poured into dilute hydrochloric acid (1.0 mol dm^{-3}, 25 cm^3), extracted with dichloromethane (3 × 15 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. The residue was dissolved in dry Et_2O (30 cm^3), powdered potassium hydroxide (1.48 g, 26.4 mmol) and dry methanol (0.81 cm^3) were added, and the reaction was stirred for 2.5 h. The reaction mixture was filtered through a pad of potassium carbonate, which was washed thoroughly with Et_2O. The solvent was then removed by careful distillation using a Vigreux column. Distillation from $MgSO_4$ (bp 117–119 °C, lit.[38] 118–129 °C) gave the epoxide **26** (587 mg, 35%) as a liquid, spectroscopically identical to that obtained previously.

1-Diphenylphosphinoylpentan-3-ol 21a

n-Butyllithium (15 cm^3 of a 1.6 mol dm^{-3} solution in hexanes, 24.0 mmol) was added dropwise to methyldiphenylphosphine oxide (20.9 mmol) in dry THF (100 cm^3) at 0 °C. After 15 min, the epoxide (22.0 mmol) was added dropwise, and the reaction was stirred for a further 4 h at 20 °C, quenched with saturated ammonium chloride solution (100 cm^3), extracted with dichloromethane (3 × 100 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product, which was purified by flash chromatography, eluting with 7% methanol in EtOAc, to give the *alcohol* **21a** (5.71 g, 95%) as an oil, R_f 0.20 (EtOAc) (Found: $M^+ - H$, 287.1190. $C_{17}H_{21}O_2P$ requires *M* − H, 287.1201); ν_{max}/cm^{-1} ($CHCl_3$) 3344 (br, OH), 1437 (P–Ph) and 1173 (P=O); δ_H (400 MHz; $CDCl_3$) 7.8–7.2 (10 H, m, Ph_2PO), 3.56 (2 H, m, C*H*OH and OH), 2.28 (2 H, m, PCH_2), 1.86 (1 H, m, $PCH_2H_AH_B$), 1.65 (1 H, m, $PCH_2H_AH_B$), 1.45 (2 H, m, CH_2Me) and 0.88 (3 H, t, *J* 7.4, Me); δ_C (100 MHz; $CDCl_3$) 133–128 (m, Ph_2PO), 72.8$^+$ (d, $^3J_{PC}$ 9.7, CHOH), 30.1$^-$, 29.0$^-$ (d, $^2J_{PC}$ 9.7), 26.3$^-$ (d, $^1J_{PC}$ 71.0, PCH_2) and 10.1$^+$ (Me); *m*/*z* 287.1 (20%, $M^+ - H$), 259.1 (80, M − Et), 215.1 (80, Ph_2POCH_2) and 202.1 (100, Ph_2POH).

3-Diphenylphosphinoyl-1-phenylpropan-1-ol 21d

By the same general method, methyldiphenylphosphine oxide (4.00 g, 18.5 mmol) and styrene oxide (2.29 cm^3, 20.0 mmol) gave a crude product which was purified by flash chromatography, eluting with 7% methanol in EtOAc, to give the alcohol[21] **21d** (5.67 g, 91%) as needles, mp 139–141 °C, spectroscopically identical to that obtained previously.

(*R*)-1-Diphenylphosphinoylheptan-3-ol 21b

By the same general method, methyldiphenylphosphine oxide (8.86 g, 41.0 mmol) and the epoxide (*R*)-**26** (4.40 cm^3, 36.5 mmol) gave a crude product which was purified by flash chromatography, eluting with 5% methanol in EtOAc, to give the alcohol[21] **21b** (7.91 g, 68% based on epoxide) as an oil, $[\alpha]_D^{20}$ −8.4 (*c* 1.26 in $CHCl_3$; 84% ee), spectroscopically identical to that obtained previously.

(*S*)-1-Cyclohexyl-3-diphenylphosphinoylpropyl benzyl ether 31c

n-Butyllithium (7.4 cm^3 of a 1.3 mol dm^{-3} solution in hexanes, 9.6 mmol) was added dropwise to the phosphine oxide (1.87 g, 8.7 mmol) in dry THF (30 cm^3) at 0 °C. After 15 min, the epoxide (*R*)-**29** (993 mg, 7.9 mmol) was added dropwise, and the reaction was stirred for a further 4 h at 20 °C, quenched with saturated ammonium chloride solution (30 cm^3), extracted with dichloromethane (3 × 20 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product which was dried on a vacuum pump for 2 h. The residue was dissolved in dry THF (40 cm^3), tetra-*n*-butylammonium iodide (144 mg, 0.39 mmol) added in one portion, sodium hydride (504 mg, 60% dispersion in oil, 12.6 mmol) added in several portions and the reaction mixture was stirred until no further gas was evolved. Benzyl bromide (1.5 cm^3, 12.7 mmol) was added dropwise to the reaction mixture, which was stirred for 16 h, quenched with water (30 cm^3), extracted with dichloromethane (3 × 25 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 *benzyl ether* **31c** (1.90 g, 56% based on epoxide **29**) as plates, mp 135–137 °C (from EtOAc–hexane); R_f 0.51 (EtOAc); $[\alpha]_D^{20}$ +3.1 (*c* 1.30 in $CHCl_3$; 89% ee) (Found: $M^+ - Bn$, 341.1670. $C_{28}H_{33}O_2P$ requires *M* − *Bn*, 341.1670); ν_{max}/cm^{-1} ($CHCl_3$) 1437 (P–Ph) and 1232 (P=O); δ_H (400 MHz; $CDCl_3$) 7.8–7.2 (15 H, m, Ph_2PO and Ph), 4.42 (1 H, d, *J* 11.5, $PhCH_AH_B$), 4.38 (1 H, d, *J* 11.5, $PhCH_AH_B$), 3.19 (1 H, m, C*H*OBn) and 2.4–0.8 (15 H, m); δ_C (100 MHz; $CDCl_3$) 138.8$^-$ (*ipso*-Ph), 134–127.5 (m, Ph_2PO and Ph), 83.3$^+$ (d, $^3J_{PC}$ 13.4, CHOBn), 71.7$^-$ ($PhCH_2$), 40.5$^+$, 29.3$^-$, 28.5$^-$, 26.5$^-$, 26.2$^-$, 24.8$^-$ (d, $^1J_{PC}$ 72.0, PCH_2), 21.9$^-$ and 21.8$^-$; *m*/*z* 341.2 (20%, $M^+ - Bn$), 201.0 (50, Ph_2PO) and 91.1 (100, Bn).

(1*S*,3*R*)- and (1*S*,3*S*)-3-Diphenylphosphinoyl-1-phenylbutyl benzyl ether 51

By the same general method, ethyldiphenylphosphine oxide (4.23 g, 18.3 mmol), (*R*)-styrene oxide (1.91 cm^3, 16.7 mmol), tetra-*n*-butylammonium iodide (305 mg, 0.82 mmol), sodium hydride (1.07 g, 60% dispersion in oil, 26.5 mmol) and benzyl bromide (3.18 cm^3, 27.9 mmol) gave a crude product which was purified by flash chromatography, eluting with EtOAc, to give the *benzyl ether* **51** (5.66 g, 80% based on the epoxide over 2 steps, 86:14 mixture of diastereomers) as an oil, R_f 0.51 (EtOAc); $[\alpha]_D^{20}$ −26.3 (*c* 2.85 in $CHCl_3$; 100% ee) (Found: MH^+, 441.1987. $C_{29}H_{29}O_2P$ requires *MH*, 441.1983); ν_{max}/cm^{-1} ($CHCl_3$) 1438 (P–Ph) and 1176 (P=O); δ_H (400 MHz; $CDCl_3$) 7.8–7.1 (20 H, m, Ph_2PO and Ph × 2), 4.33 (1 H, d, *J* 11.8, $PhCH_AH_B$), 4.22 (1 H, t, *J* 6.5, C*H*OBn), 4.09 (d, *J* 11.8, $PhCH_AH_B$), 2.25 (1 H, m), 2.1–1.9 (2 H, m) and 1.16 (3 H, dd, *J* 7.1 and $^3J_{PH}$ 14.6, Me); δ_C (100 MHz; $CDCl_3$) 141.8$^-$ (*ipso*-Ph^{min}), 141.0$^-$ (*ipso*-Ph^{maj}), 138.5$^-$ (*ipso*-Ph^{min}), 138.4$^-$ (*ipso*-Ph^{maj}), 132–126 (m, Ph_2PO and Ph × 2), 79.9$^+$ (d, $^3J_{PC}$ 12.3, CHOBn^{maj}), 77.9$^+$ (d, $^3J_{PC}$ 12.7, CHOBn^{min}), 70.4$^-$ ($PhCH_2^{min}$), 70.3$^-$ ($PhCH_2^{maj}$), 38.1$^-$ (min), 37.6$^-$ (maj), 28.5$^+$ (d, $^1J_{PC}$ 72.0, PCH_2^{maj}), 28.2$^+$ (d, $^1J_{PC}$ 72.3, PCH_2^{min}), 13.6$^+$ (Me^{maj}) and 11.7$^+$ (Me^{min}); *m*/*z* (FAB) 441 (75%, MH^+), 333.3 (100, M − BnO).

3-Diphenylphosphinoylpropyl benzyl ether 12

3-Diphenylphosphinoylpropan-1-ol **11** (3.50 g, 13.5 mmol) was dissolved in dry THF (80 cm^3), tetra-*n*-butylammonium iodide (246 mg, 0.67 mmol) added in one portion, sodium hydride (868 mg, 60% dispersion in oil, 21.7 mmol) added in several portions and the reaction mixture was stirred until no further gas was evolved. Benzyl bromide (2.56 cm^3, 21.7 mmol) was added dropwise to the reaction mixture, which was stirred for 16 h,

quenched with water (50 cm^3), extracted with dichloromethane (3 × 50 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 *benzyl ether* **12** (4.05 g, 86%) as needles, mp 64–66 °C (from EtOAc–hexane); R_f 0.20 (EtOAc) (Found: C, 75.3; H, 6.55; P, 8.8%; $M^+ - Bn$, 259.0880. $C_{22}H_{21}O_2P$ requires C, 75.4; H, 6.60; P, 8.8%; *M* − *Bn*, 259.0889); ν_{max}/cm^{-1} ($CHCl_3$) 1437 (P–Ph) and 1171 (P=O); δ_H (400 MHz; $CDCl_3$) 7.74–7.2 (15 H, m, Ph_2PO and Ph), 4.38 (2 H, s, PhCH_2), 3.49 (2 H, t, *J* 6.0, CH_2OBn), 2.36 (2 H, m) and 1.91 (2 H, m); δ_C (63 MHz; $CDCl_3$) 138.3^- (*ipso*-Ph), 133–127 (m, Ph_2PO and remaining Ph), 72.8^- (PhCH_2), 70.0^- (d, $^3J_{PC}$ 14.4, CH_2OBn), 26.5^- (d, $^1J_{PC}$ 72.5, PCH_2) and 22.0^-; *m*/*z* 259.1 (100%, $M^+ - Bn$), 201.0 (70, Ph_2PO) and 91.1 (85, Bn).

1-Diphenylphosphinoylpentan-3-yl benzyl ether 31a

By the same general method, 1-diphenylphosphinoylpentan-3-ol **21a** (1.02 g, 3.54 mmol), tetra-*n*-butylammonium iodide 65 mg, 0.18 mmol), sodium hydride (228 mg, 60% dispersion in oil, 5.7 mmol) and benzyl bromide (0.67 cm^3, 5.7 mmol) gave a crude product which was purified by flash chromatography, eluting with EtOAc, to give the *benzyl ether* **31a** (1.17 g, 90%) as an oil, R_f 0.30 (EtOAc) (Found: $M^+ - Bn$, 287.1196. $C_{24}H_{25}O_2P$ requires *M* − *Bn*, 287.1223); ν_{max}/cm^{-1} ($CHCl_3$) 1437 (P–Ph) and 1171 (P=O); δ_H (400 MHz; $CDCl_3$) 7.8–7.1 (15 H, m, Ph_2PO and Ph), 4.42 (2 H, AB q, *J* 11.7, PhCH_2), 3.39 (1 H, dq, *J* 4.3 and 6.1, C*H*OBn), 2.38 (1 H, dddd, *J* 4.8, 10.5, 11.9 and 15.4, PCH_AH_B), 2.24 (1 H, dddd, *J* 4.3, 11.9, 12.8 and 14.0, PCH_AH_B), 2.0–1.4 (4 H, m) and 0.87 (3 H, t, *J* 7.5, Me); δ_C (63 MHz; $CDCl_3$) 144.7^- (*ipso*-Ph), 135–128 (m, Ph_2PO and remaining Ph), 80.7^+ (d, $^3J_{PC}$ 13.6, *C*HOBn), 71.7^- (CH_2Ph), 27.0^-, 25.8^- (d, $^1J_{PC}$ 72.5, PCH_2), 25.6^- (d, $^2J_{PC}$ 3.0, PCH_2CH_2) and 10.6^+ (Me); *m*/*z* 287.1 (100%, $M^+ - Bn$), 201.0 (70, Ph_2PO), 105 (90) and 91.1 (90, Bn).

(*R*)-1-Diphenylphosphinoylheptan-3-yl benzyl ether 31b

By the same general method, (*R*)-1-diphenylphosphinoylheptan-3-ol **21b** (7.73 g, 24.5 mmol), tetra-*n*-butylammonium iodide (200 mg, 0.54 mmol), sodium hydride (1.58 mg, 60% dispersion in oil, 39.5 mmol) and benzyl bromide (4.65 cm^3, 39.3 mmol) gave a crude product which was purified by flash chromatography, eluting with 4:1 EtOAc–hexane, to give the *benzyl ether* **31b** (9.23 g, 93%) as an oil, R_f 0.41 (EtOAc); $[a]_D^{20}$ +4.3 (*c* 1.93 in $CHCl_3$; 84% ee) (Found: $M^+ - Bn$, 349.1355. $C_{26}H_{29}O_2P$ requires *M* − *Bn*, 349.1355); ν_{max}/cm^{-1} ($CHCl_3$) 1438 (P–Ph) and 1200 (P=O); δ_H (400 MHz; $CDCl_3$) 7.8–7.25 (15 H, m, Ph_2PO and Ph), 4.44 (1 H, d, *J* 11.7, PhCH_AH_B), 4.37 (1 H, d, *J* 11.7, PhCH_AH_B), 3.44 (1 H, quin, *J* 5.8, C*H*OBn), 2.5–1.1 (10 H, m) and 0.85 (3 H, t, *J* 6.7, Me); δ_C (63 MHz; $CDCl_3$) 138.6^- (*ipso*-Ph), 134–127 (m, Ph_2PO and remaining Ph), 78.3^+ (d, $^3J_{PC}$ 13.8, *C*HOBn), 70.6^- (CH_2Ph), 32.9^-, 27.4^-, 24.9^-, 24.7^- (d, $^1J_{PC}$ 73.0, PCH_2) and 13.9^+ (Me); *m*/*z* 287.1 (100%, $M^+ - Bn$), 201.0 (70, Ph_2PO), 105 (90) and 91.1 (90, Bn).

3-Diphenylphosphinoyl-1-phenylpropyl benzyl ether 31d

By the same general method, 3-diphenylphosphinoyl-1-phenylpropan-1-ol **21d** (1.29 g, 3.85 mmol), tetra-*n*-butylammonium iodide (60 mg, 0.19 mmol), sodium hydride (247 mg, 60% dispersion in oil, 6.2 mmol) and benzyl bromide (0.73 cm^3, 6.2 mmol) gave a crude product which was purified by flash chromatography, eluting with EtOAc, to give the *benzyl ether* **31d** (1.44 g, 88%) as needles, mp 139–141 °C (from EtOAc–hexane); R_f 0.46 (EtOAc) (Found: C, 78.9; H, 6.35; P, 7.4%; $M^+ - Bn$, 335.1200. $C_{28}H_{27}O_2P$ requires C, 78.9; H, 6.40; P, 7.3%; *M* − *Bn*, 335.1201); ν_{max}/cm^{-1} ($CHCl_3$) 1437 (P–Ph) and 1173 (P=O); δ_H (400 MHz; $CDCl_3$) 7.7–7.2 (20 H, m, Ph_2PO and 2 × Ph), 4.46 (1 H, d, *J* 11.8, PhCH_AH_B), 4.42 (1 H, t, *J* 6.3, C*H*OBn), 4.24 (1 H, d, *J* 11.8, PhCH_AH_B), 2.45 (1 H, m), 2.25 (1 H, m) and 2.08 (2 H, m); δ_C (50 MHz; $CDCl_3$) 141.1^- (*ipso*-Ph), 138.4^- (*ipso*-Ph), 132–126^+ (m, Ph_2PO and remaining Ph), 80.9^- (d, $^3J_{PC}$ 14.0, CHOBn), 70.4^- (PhCH_2), 29.9^- and 25.7^- (d, $^1J_{PC}$ 72.4, PCH_2); *m*/*z* 335.1 (100%, $M^+ - Bn$), 201.0 (50, Ph_2PO) and 91.1 (60, Bn).

3-Diphenylphosphinoylpropyl 4-nitrobenzyl ether 14

By the same general method, 3-diphenylphosphinoylpropan-1-ol **13** (1.55 g, 5.98 mmol), tetra-*n*-butylammonium iodide (176 mg, 0.49 mmol), sodium hydride (386 mg, 60% dispersion in oil, 9.7 mmol) and 4-nitrobenzyl bromide (2.06 g, 9.6 mmol) gave a crude product which was purified by flash chromatography, eluting with 5% methanol in EtOAc, to give the 4-*nitrobenzyl ether* **14** (0.60 g, 26%) as an oil; R_f 0.20 (EtOAc) (Found: $M^+ - ArCH_2$, 259.0890. $C_{22}H_{22}NO_4P$ requires *M* − *Ar*CH_2, 259.0889); ν_{max}/cm^{-1} ($CHCl_3$) 1683 (C=O), 1521 (NO_2), 1423 (P–Ph), 1344 (NO_2) and 1161 (P=O); δ_H (400 MHz; $CDCl_3$) 8.20 (2 H, d, *J* 8.6, Ar), 7.8–7.4 (12 H, m, Ph_2PO and remaining Ar), 4.52 (2 H, s, ArCH_2), 3.56 (2 H, t, *J* 6.5, CH_2OCH_2Ar), 2.5–2.3 (2 H, m, PCH_2) and 2.05–1.9 (2 H, m); δ_C (50 MHz; $CDCl_3$) 155.9^+ (Ar), 145.9^- (Ar), 133–127^+ (m, Ph_2PO and remaining Ar), 123.5^+, 71.4^- (ArCH_2), 70.6^- (d, $^3J_{PC}$ 14.3, CH_2OCH_2Ar), 26.3^- (d, $^1J_{PC}$ 72.3, PCH_2) and 21.9^- (d, $^2J_{PC}$ 3.5, PCH_2CH_2); *m*/*z* 259.1 (100%, $M^+ - ArCH_2$), 215.1 (50, Ph_2POCH_2) and 201.1 (55, Ph_2PO).

1-Diphenylphosphinoylpentan-3-yl methoxymethyl ether 32

Methoxymethyl chloride (1.3 cm^3, 17.2 mmol) and diisopropylethylamine (2.45 cm^3, 14.0 mmol) were added dropwise to a solution of 1-diphenylphosphinoylpentan-3-ol **21a** (1.04 g, 3.6 mmol) in dry dichloromethane (40 cm^3) at 0 °C. The solution was stirred for 1 h, allowed to warm to room temperature, stirred for a further 15 h, quenched with saturated sodium carbonate (50 cm^3), extracted with dichloromethane (3 × 50 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 *methoxymethyl ether* **32** (1.20 g, 100%) as an oil; R_f 0.22 (EtOAc) (Found: $M^+ - Bn$, 333.1622. $C_{19}H_{25}O_3P$ requires *M* − *Bn*, 333.1622); ν_{max}/cm^{-1} ($CHCl_3$) 1437 (P–Ph) and 1200 (P=O); δ_H (400 MHz; $CDCl_3$) 7.8–7.25 (10 H, m, Ph_2PO), 4.57 (2 H, AB q, *J* 6.7, OCH_2OMe), 3.51 (1 H, m, CHOMOM), 3.31 (3 H, OMe), 2.49 (1 H, m, PCH_AH_B), 2.27 (1 H, m, PCH_AH_B), 1.89 (1 H, m), 1.73 (1 H, m), 1.52 (2 H, m) and 0.84 (3 H, t, *J* 7.4, Me); δ_C (50 MHz; $CDCl_3$) 134–128^+ (m, Ph_2PO), 95.3^- (OCH_2O), 78.3^+ (d, $^3J_{PC}$ 14.7, CHOMOM), 55.4^+ (OMe), 25.8^- (d, $^1J_{PC}$ 68.4, PCH_2), 25.6^-, 24.2^- and 9.4^+; *m*/*z* 333.2 (40%, M^+), 287.1 (100, $M - MeOCH_2$) and 201.0 (80, Ph_2PO).

(1*R**,2*S**)-2-Diphenylphosphinoyl-1-(4-methoxyphenyl)hexan-1-ol 17a

n-Butyllithium (9.1 cm^3 of a 1.3 mol dm^{-3} solution in hexanes, 11.8 mmol) was added dropwise to pentyldiphenylphosphine oxide (7.27 g, 11.0 mmol) in dry THF (30 cm^3) at −78 °C. After 15 min, freshly distilled *p*-anisaldehyde (3.7 cm^3, 30.5 mmol) was added dropwise, the reaction was stirred for 30 min at −78 °C, warmed gradually to room temperature over 1 h, quenched with water (30 cm^3), extracted with dichloromethane (3 × 30 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product. Analysis of the crude product by 400 MHz ^1H NMR showed it to consist of a 72:28 ratio of **17a**:**18a**. Purification by flash chromatography, eluting with 1:1 EtOAc–hexane to give the *alcohol* **17a** (7.70 g, 71%) as needles, mp 141–142 °C (from EtOAc–hexane); R_f 0.48 (EtOAc) (Found: C, 73.5; H, 7.25; P, 7.7%; M^+, 408.1845. $C_{25}H_{29}O_3P$ requires C, 73.5; H, 7.60; P, 7.2%; *M*, 408.1854); ν_{max}/cm^{-1}

($CHCl_3$) 3382 (OH), 1439 (P–Ph) and 1163 (P=O); δ_H (200 MHz; $CDCl_3$) 8.0–7.3 (10 H, m, Ph_2PO), 7.23 (2 H, br d, *J* 8.6, Ar), 6.81 (2 H, br d, *J* 8.7, Ar), 5.22 (1 H, br d, $^3J_{PH}$ 9.1, C*H*OH), 4.83 (1 H, br s, OH), 3.74 (3 H, s, OMe), 2.36 (1 H, br q, *J* 5.1, PCH), 2.0–0.6 (6 H, m) and 0.45 (3 H, t, *J* 7.4, Me); δ_C (50 MHz; $CDCl_3$) 158.4$^-$ (*ipso*-Ar), 134.5–126 (m, Ph_2PO and remaining Ar), 113.6$^+$ (Ar), 70.4$^+$ (CHOH), 55.1$^+$ (OMe), 44.6$^+$ (d, $^1J_{PC}$ 66, PCH), 31.8$^-$ (d, $^2J_{PC}$ 5.6), 22.2$^-$, 20.5$^-$ and 13.2$^+$ (Me); *m*/*z* 408.2 (20%, M^+), 229.1 (95) and 135 (100, ArCHO).

Also obtained was the *alcohol* **18a** (2.86 g, 26%) as needles, mp 174–176 °C (from EtOAc–hexane); R_f 0.23 (EtOAc) (Found: M^+, 408.1853. $C_{25}H_{29}O_3P$ requires *M*, 408.1854); ν_{max}/cm^{-1} ($CHCl_3$) 3363 (OH), 1438 (P–Ph) and 1173 (P=O); δ_H (200 MHz; $CDCl_3$) 7.8–7.2 (10 H, m, Ph_2PO), 7.17 (2 H, br d, *J* 8.6, Ar), 6.66 (2 H, br d, *J* 8.6, Ar), 5.54 (1 H, d, *J* 5.1, OH), 4.98 (1 H, td, *J* 5.5 and $^3J_{PH}$ 16.7, OH), 3.68 (3 H, s, OMe), 2.66 (1 H, dq, *J* 4.0 and 7.1, PCH), 1.6–0.8 (6 H, m) and 0.58 (3 H, t, *J* 6.7, Me); δ_C (50 MHz; $CDCl_3$) 158.7$^-$ (*ipso*-Ar), 135–127 (m, Ph_2PO and remaining Ar), 113.2$^+$ (Ar), 70.4$^+$ (d, $^2J_{PC}$ 3.1, CHOH), 55.0$^+$ (OMe), 44.6$^+$ (d, $^1J_{PC}$ 66.5, PCH), 31.8$^-$ (d, $^2J_{PC}$ 9.1), 26.2$^-$, 22.2$^-$ and 13.4$^+$ (Me); *m*/*z* 408.2 (40%, M^+), 229.1 (100) and 202.1 (60, Ph_2POH).

(2*E*,4*R**,5*S**)-5-Diphenylphosphinoyl-3-methylnon-2-en-4-ol 17b

By the same general method, pentyldiphenylphosphine oxide (1.97 g, 7.3 mmol) and *trans*-2-methylbut-2-enal (0.77 cm^3, 8.0 mmol) in THF gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to consist of a 51:49 ratio of **17b**:**18b**. Purification by flash chromatography eluting with 3:2 EtOAc–hexane gave the *alcohol* **17b** (1.22 g, 47%) as needles, mp 131–132 °C (from EtOAc–hexane); R_f 0.51 (EtOAc) (Found: C, 74.4; H, 8.35; P, 8.8%; M^+, 356.1889. $C_{28}H_{29}O_2P$ requires C, 74.1; H, 8.35; P, 8.7%; *M*, 356.1905); ν_{max}/cm^{-1} ($CHCl_3$) 3367 (br s, OH), 1673 (C=C), 1437 (P–Ph) and 1164 (P=O); δ_H (400 MHz; $CDCl_3$) 8.0–7.35 (10 H, m, Ph_2PO), 5.73 (1 H, q, *J* 6.9, C=CH), 4.54 (s, OH), 4.36 (1 H, br d, $^3J_{PH}$ 10.0, C*H*OH), 2.28 (1 H, q, *J* 5.2, PCH), 1.78 (2 H, m), 1.58 (3 H, d, *J* 7.0, Me), 1.56–0.8 (4 H, m), 1.48 (3 H, s, Me) and 0.62 (3 H, t, *J* 7.0, Me); δ_C (63 MHz; $CDCl_3$) 133–128 (m, Ph_2PO and *C*=CH), 119.9$^+$ (C=*C*H), 72.4$^+$ (d, $^2J_{PC}$ 2.4, CHOH), 39.7$^+$ (d, $^1J_{PC}$ 67.9, PCH), 32.5$^-$ (d, $^2J_{PC}$ 5.7, PCH*C*H$_2$), 22.6$^-$, 21.1$^-$, 14.1$^+$ (d, $^4J_{PC}$ 2.4, CH=C*Me*), 13.5$^+$ (Me) and 13.1$^+$ (Me); *m*/*z* 356.2 (20%, M^+), 229.1 (100) and 202.1 (50, Ph_2POH).

Also obtained was the *alcohol* **18b** (1.15 g, 45%) as an oil, R_f 0.37 (EtOAc) (Found: M^+, 356.1910. $C_{28}H_{29}O_2P$ requires *M*, 356.1905); ν_{max}/cm^{-1} ($CHCl_3$) 3430 (br s, OH), 1670 (C=C), 1437 (P–Ph) and 1148 (P=O); δ_H (400 MHz; $CDCl_3$) 7.9–7.3 (10 H, m, Ph_2PO), 5.48 (1 H, q, *J* 6.7, C=CH), 5.09 (d, *J* 5.0, OH), 4.28 (1 H, td, *J* 5.6 and $^3J_{PH}$ 15.6, C*H*OH), 2.54 (1 H, m, PCH), 1.7–0.8 (6 H, m), 1.42 (3 H, s, Me), 1.36 (3 H, d, *J* 7.3) and 0.73 (3 H, t, *J* 7.3, Me); δ_C (63 MHz; $CDCl_3$) 135.0 (d, $^3J_{PC}$ 8.4, CH=*C*), 134–128 (m, Ph_2PO), 122.7$^+$ (C=*C*H), 77.7$^+$ (d, $^2J_{PC}$ 3.9, CHOH), 39.8$^+$ (d, $^1J_{PC}$ 67.7, PCH), 30.5$^-$ (d, $^2J_{PC}$ 9.1, PCH*C*H$_2$), 26.5$^-$, 22.6$^-$, 13.7$^+$ (Me), 12.9$^+$ (Me) and 12.2$^+$ (Me); *m*/*z* 356.2 (25%, M^+), 229.1 (100) and 202.1 (55, Ph_2POH).

(3*R**,4*S**)-4-Diphenylphosphinoyl-2-methyloct-1-en-3-ol 17c

By the same general method, pentyldiphenylphosphine oxide (2.13 g, 7.9 mmol) and methacrolein (0.71 cm^3, 8.6 mmol) in THF gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to consist of a 59:41 ratio of **17c**:**18c**. Purification by flash chromatography eluting with 3:2 EtOAc–hexane gave the *alcohol* **17c** (1.52 g, 56%) as needles, mp 129–130 °C (from EtOAc–hexane); R_f 0.50 (EtOAc) (Found: C, 73.5; H, 8.00; P, 9.2%; MH^+, 343.1827. $C_{27}H_{27}O_2P$ requires C, 73.7; H,7.95; P, 9.1%; *MH*, 343.1824); ν_{max}/cm^{-1} ($CHCl_3$) 3382 (br s, OH), 1653 (C=C), 1438 (P–Ph) and 1164 (P=O); δ_H (400 MHz; $CDCl_3$) 8.0–7.4 (10 H, m, Ph_2PO), 5.21 (1 H, br s, C=CH_AH_B), 5.93 (1 H, br s, C=CH$_A$$H_B$), 4.63 (s, OH), 4.38 (1 H, br d, $^3J_{PH}$ 10.4, C*H*OH), 2.29 (1 H, q, *J* 6.9, PCH), 1.9–0.7 (6 H, m), 1.61 (3 H, s, Me) and 0.62 (3 H, t, *J* 6.7, Me); δ_C (63 MHz; $CDCl_3$) 143.0$^-$ (d, $^3J_{PC}$ 13.8, *C*=CH_2), 133–128 (m, Ph_2PO), 111.8$^-$ (C=*C*H$_2$), 71.9$^+$ (d, $^2J_{PC}$ 2.3, CHOH), 39.5$^+$ (d, $^1J_{PC}$ 68.6, PCH), 32.4$^-$ (d, $^2J_{PC}$ 5.1), 22.6$^-$, 20.7$^-$, 19.8$^+$ (Me) and 13.5$^+$ (Me); *m*/*z* (FAB) 343.2 (20%, MH^+), 229.1 (100) and 202.1 (60, Ph_2POH).

Also obtained was the *alcohol* **18c** (0.93 g, 34%) as an oil, R_f 0.38 (EtOAc) (Found: M^+, 342.1740. $C_{27}H_{27}O_2P$ requires *M*, 342.1749); ν_{max}/cm^{-1} ($CHCl_3$) 3357 (br s, OH), 1653 (C=C), 1438 (P–Ph) and 1149 (P=O); δ_H (400 MHz; $CDCl_3$) 7.9–7.35 (10 H, m, Ph_2PO), 5.05 (d, *J* 4.8, OH), 4.96 (1 H, br s, C=CH_A-H_B), 4.74 (1 H, br s, C=CH$_A$$H_B$), 4.37 (1 H, ddd, *J* 5.1, 7.0 and $^3J_{PH}$ 15.5, C*H*OH), 2.57 (1 H, m, PCH), 2.2–0.8 (6 H, m), 1.66 (3 H, s, Me) and 0.77 (3 H, t, *J* 7.3, Me); δ_C (63 MHz; $CDCl_3$) 144.4$^-$ (d, $^3J_{PC}$ 8.7, *C*=CH_2), 134–128 (m, Ph_2PO), 113.9$^-$ (C=*C*H$_2$), 76.5$^+$ (d, $^2J_{PC}$ 4.0, CHOH), 39.1$^+$ (d, $^1J_{PC}$ 67.6, PCH), 30.5$^-$ (d, $^2J_{PC}$ 8.3), 26.5$^-$, 22.6$^-$, 17.6$^+$ (Me) and 13.6$^+$ (Me); *m*/*z* 342.2 (10%, M^+), 229.1 (100) and 202.1 (60, Ph_2POH).

(1*R**,2*S**)-4-Benzyloxy-2-diphenylphosphinoyl-1-(4-methoxyphenyl)butan-1-ol 17d

By the same general method, 3-diphenylphosphinoylpropyl benzyl ether **12** (3.61 g, 10.3 mmol) and *p*-anisaldehyde (1.43 cm^3, 11.4 mmol) in THF gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to consist of a 80:20 ratio of **17d**:**18d**. Purification by flash chromatography eluting with 1:1 EtOAc–hexane gave the *alcohol* **17d** (3.68 g, 73%) as an oil, R_f 0.53 (EtOAc) (Found: M^+, 468.1972. $C_{30}H_{31}O_4P$ requires *M*, 486.1959); ν_{max}/cm^{-1} ($CHCl_3$) 3440 (OH) and 1438 (P–Ph); δ_H (400 MHz; $CDCl_3$) 8.0–7.05 (17 H, m, Ph_2PO, Ph and remaining Ar), 6.85 (2 H, br d, *J* 8.7, Ar), 5.24 (1 H, d, *J* 9.0, C*H*OH), 4.88 (1 H, s, OH), 4.00 (2 H, AB q, *J* 13.0, $PhCH_2$), 3.77 (3 H, OMe), 2.86 (2 H, m, CH_2OBn), 2.63 (1 H, dt, *J* 5.5 and 9.2, PCH) and 2.4–1.8 (2 H, m); δ_C (100 MHz; $CDCl_3$) 158.6$^-$ (*ipso*-Ar), 138.4$^-$ (*ipso*-Ph), 135–126 (m, Ph_2PO and remaining Ar and Ph), 113.5$^+$ (Ar), 72.1$^-$ (Ph*C*H$_2$), 69.9$^+$ (CHOH), 68.3$^-$ (d, $^3J_{PC}$ 7.4, *C*H$_2$OBn), 55.1$^+$ (OMe), 40.2$^+$ (d, $^1J_{PC}$ 67.5, PCH) and 21.2$^-$; *m*/*z* 486.2 (30%, M^+), 377.1 (90), 135.0 (95, CH_2CH_2OBn) and 77.0 (100, Ph).

(1*R**,2*S**)-4-Benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)butan-1-ol 17e

By the same general method, 3-diphenylphosphinoylpropyl benzyl ether **12** (1.08 g, 3.09 mmol) and furfural (0.28 cm^3, 3.40 mmol) in THF gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to consist of a 82:18 ratio of **17e**:**18e**. Purification by flash chromatography eluting with 4:1 EtOAc–hexane gave the *alcohol* **17e** (1.13 g, 82%) as an oil, R_f 0.44 (EtOAc) (Found: M^+, 446.1651. $C_{27}H_{27}O_4P$ requires *M*, 446.1647); ν_{max}/cm^{-1} ($CHCl_3$) 3376 (OH) and 1148 (P–Ph); δ_H (400 MHz; $CDCl_3$) 7.93–7.21 (16 H, m, Ph_2PO, Ph and remaining Ar), 6.34 (1 H, d, *J* 3.2, Ar), 6.29 (1 H, dd, *J* 1.8 and 3.1, Ar), 5.26 (1 H, d, *J* 9.4, C*H*OH), 4.83 (1 H, br s, OH), 4.17 (2 H, AB q, *J* 11.9, $PhCH_2$), 3.15–2.95 (2 H, m), 2.73 (1 H, dt, *J* 5.0 and 8.8, PCH), 2.22 (1H, m) and 1.93 (1 H, m); δ_C (100 MHz; $CDCl_3$) 154.2$^-$ (d, $^3J_{PC}$ 14.2, *ipso*-Ar), 141.0$^-$ (*ipso*-Ph), 133–127 (m, Ph_2PO and remaining Ar and Ph), 110.7$^+$, 106.6$^+$ (Ar × 2), 72.5$^-$ (Ph*C*H$_2$), 68.0$^+$ (d, $^3J_{PC}$ 8.1, CHOBn), 66.8$^+$ (CHOH), 37.8$^+$ (d, $^1J_{PC}$ 69.4, PCH) and 22.2$^-$; *m*/*z* 446.2 (90%, M^+), 202.1 (100, Ph_2POH) and 91.1 (95, Bn).

(3*R**,4*S**)-6-Benzyloxy-4-diphenylphosphinoyl-2-methylhex-1-en-3-ol 17f

By the same general method, 3-diphenylphosphinoylpropyl benzyl ether **12** (989 mg, 2.83 mmol) and methacrolein (0.25 cm^3, 3.1 mmol) in THF gave a crude product. Analysis of the

crude product by 400 MHz ^{1}H NMR showed it to consist of a 80:20 ratio of **17f**:**18f**. Purification by flash chromatography eluting with 1:1 EtOAc–hexane gave the *alcohol* **17f** (722 mg, 63%) as an oil, R_f 0.46 (EtOAc) (Found: MH^+, 421.1933. $C_{26}H_{29}O_3P$ requires *MH*, 421.1932); ν_{max}/cm^{-1} ($CHCl_3$) 3387 (br s, OH), 1654 (C=C), 1438 (P–Ph) and 1164 (P=O); δ_H (400 MHz; $CDCl_3$) 7.9–7.2 (15 H, m, Ph_2PO and Ph), 5.24 (br s, C=CH_A-H_B), 4.94 (br s, C=C$H_A H_B$), 4.65 (1 H, s, OH), 4.40 (1 H, d, *J* 10.3, C*H*OH), 4.35 (1 H, d, *J* 12.0, PhC$H_A H_B$), 4.23 (1 H, d, *J* 12.0, PhC$H_A H_B$), 3.31 (1 H, m), 3.05 (1 H, m), 2.78 (1 H, br q, *J* 5.7, PCH), 2.3–1.9 (2 H, m) and 1.63 (3 H, s, Me); δ_C (50 MHz; $CDCl_3$) 143.2$^-$ (d, $^3J_{PC}$ 13.6, CH_2=*C* Me), 138.5$^-$ (*ipso*-Ph), 131–126 (m, Ph_2PO and remaining Ph), 111.7$^-$ (CH_2=*C* Me), 72.4$^-$ (Ph*C*H_2), 71.6$^+$ (CHOH), 68.4$^-$ (d, $^2J_{PC}$ 6.2, *C*HOBn), 35.0$^+$ (d, $^1J_{PC}$ 69.8, PCH), 21.4$^-$ and 19.5$^+$ (Me); *m*/*z* (FAB) 421.2 (25%, MH^+), 244.1 (90) and 229.1 (100).

(1*S*,2*R*,4*R*)- and (1*R*,2*S*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-(4-methoxyphenyl)octan-1-ol 35d and 36d

By the same general method, (*R*)-1-diphenylphosphinoylheptan-3-yl benzyl ether **31b** (7.58 g, 18.8 mmol) and *p*-anisaldehyde (2.52 cm^3, 20.7 mmol) in THF gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to be an 62:38 ratio of **35d**:**36d**. Purification by flash chromatography eluting with 3:2 EtOAc–hexane gave the *alcohols* **35d** and **36d** (6.16 g, 60%, 61:39 ratio of diastereomers) as an oil. Further purification by HPLC eluting with chloroform gave the *alcohol* **35d** (2.34 g, 23%) as an oil, retention time 19.5 min; R_f 0.62 (EtOAc); $[\alpha]_D^{20}$ +22.8 (*c* 0.2 in $CHCl_3$; 84% ee) (Found: M^+, 542.2581. $C_{34}H_{39}O_4P$ requires *M*, 542.2586); ν_{max}/cm^{-1} ($CHCl_3$) 3431 (OH) and 1438 (P–Ph); δ_H (400 MHz; $CDCl_3$) 7.9–7.1 (17 H, m, Ph_2PO, Ph and remaining Ar), 6.83 (2 H, d, *J* 8.8, Ar), 5.19 (1 H, br d, *J* 9.9, C*H*OH), 4.80 (1 H, s, OH), 4.10 (1 H, d, *J* 12.1, PhC$H_A H_B$), 3.93 (1 H, d, *J* 12.1, PhC$H_A H_B$), 3.77 (3 H, OMe), 2.64 (1 H, m), 2.33 (1 H, m), 2.1–0.9 (8 H, m) and 0.75 (3 H, t, *J* 6.6, Me); δ_C (100 MHz; $CDCl_3$) 158.8$^-$ (*ipso*-Ar), 139.2$^-$ (*ipso*-Ph), 134–126 (m, Ph_2PO and remaining Ph and Ar), 113.5$^+$ (Ar), 76.6$^+$ (d, $^3J_{PC}$ 3.6, Ph*C*HOBn), 71.0$^+$ (CHOH), 69.2$^-$ (Ph*C*H_2), 55.2$^+$ (OMe), 40.7$^+$ (d, $^1J_{PC}$ 67.5, PCH), 33.1$^-$, 27.1$^-$, 25.9$^-$, 22.7$^-$ and 14.0$^+$ (Me); *m*/*z* 542.3 (45%, M^+), 135.0 (90) and 91.1 (100, Bn).

Also obtained was the *alcohol* **36d** (1.71 g, 18%) as an oil, retention time 17 min; R_f 0.62 (EtOAc); $[\alpha]_D^{20}$ −14.6 (*c* 0.56 in $CHCl_3$; 84% ee) (Found: M^+, 542.2581. $C_{34}H_{39}O_4P$ requires *M*, 542.2586); ν_{max}/cm^{-1} ($CHCl_3$) 3398 (OH) and 1438 (P–Ph); δ_H (400 MHz; $CDCl_3$) 7.9–7.2 (15 H, m, Ph_2PO and Ph), 7.14 (2 H, d, *J* 8.7, Ar), 6.82 (2 H, d, *J* 8.7, Ar), 5.17 (1 H, br d, *J* 8.8, C*H*OH), 4.94 (1 H, s, OH), 4.24 (1 H, d, *J* 11.1, PhC$H_A H_B$), 3.81 (3 H, OMe), 3.69 (1 H, d, *J* 11.1, PhC$H_A H_B$), 2.84 (1 H, t, *J* 7.6, PCH), 2.3–2.15 (2 H, m), 1.55 (1 H, m), 1.3–0.83 (6 H, m) and 0.77 (3 H, t, *J* 7.2, Me); δ_C (100 MHz; $CDCl_3$) 158.7$^-$ (*ipso*-Ar), 139.3$^-$ (*ipso*-Ph), 135–126 (m, Ph_2PO and remaining Ph and Ar), 113.6$^+$ (Ar), 78.6$^+$ (d, $^3J_{PC}$ 9.1, Ph*C*HOBn), 71.2$^-$ (Ph*C*H_2), 69.5$^+$ (CHOH), 55.3$^+$ (OMe), 40.6$^+$ (d, $^1J_{PC}$ 67.4, PCH), 33.4$^-$, 26.8$^-$, 26.0$^-$, 22.8$^-$ and 13.9$^+$ (Me); *m*/*z* 542.3 (55%, M^+), 201.0 (95, Ph_2PO) and 91.0 (100, Bn).

(1*R**,2*S**,4*S**)- and (1*R**,2*S**,4*R**)-4-Benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)hexan-1-ol 35a and 36a

By the same general method, 1-diphenylphosphinoylpentan-3-yl benzyl ether **31a** (216 mg, 0.57 mmol) and furfural (55 µl, 0.66 mmol) in THF gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to be a 73:18:5:5 ratio of diastereomers. Purification by flash chromatography eluting with 2:1 EtOAc–hexane gave the *alcohols* **35a** and **36a** (171 mg, 64%, 78:22 ratio of diastereomers) as an oil. Further purification by HPLC eluting with chloroform gave the *alcohol* **35a** (95 mg, 36%) as an oil, retention time 18.5 min; R_f 0.51 (EtOAc) (Found: M^+, 474.1945. $C_{29}H_{31}O_4P$ requires *M*, 474.1959); ν_{max}/cm^{-1} ($CHCl_3$) 3359 (OH), 1438 (P–Ph) and 1188 (P=O); δ_H (400 MHz; $CDCl_3$) 7.8–7.7 (2 H, m), 7.55–7.25 (14 H, m, Ph_2PO, Ph and remaining Ar), 6.38 (1 H, dd, *J* 0.9 and 3.1, Ar), 6.27 (1 H, dd, *J* 1.8 and 3.2, Ar), 5.22 (1 H, br d, *J* 9.9, C*H*OH), 4.76 (1 H, br s, OH), 4.31 (1 H, d, *J* 12.1, PhC$H_A H_B$), 4.05 (1 H, d, *J* 12.1, PhC$H_A H_B$), 2.86 (1 H, m), 2.32 (1 H, m), 2.05 (1 H, m), 1.80 (1 H, m), 1.5–1.3 (2 H, m) and 0.49 (3 H, t, *J* 7.5, Me); δ_C (100 MHz; $CDCl_3$) 153.9$^-$ (d, $^3J_{PC}$ 13.9, *ipso*-Ar), 141.1$^+$ (Ar), 138.9$^-$ (*ipso*-Ph), 132–127 (m, Ph_2PO and Ph), 110.4$^+$ (Ar), 106.9$^+$ (Ar), 77.5$^+$, 69.7$^-$ (Ph*C*H_2), 67.5$^+$, 38.0$^+$ (d, $^1J_{PC}$ 68.6, PCH), 26.2$^-$, 25.6$^-$ and 9.0$^+$ (Me); *m*/*z* 474.2 (10%, M^+), 229.1 (90), 201.1 (100, Ph_2PO) and 91.1 (90, Bn).

Also obtained was the *alcohol* **36a** (23 mg, 9%, 85:15 ratio of diastereomers) as an oil, retention time 16.5 min; R_f 0.51 (EtOAc) (Found: M^+, 528.2423. $C_{29}H_{31}O_4P$ requires *M*, 528.2429); ν_{max}/cm^{-1} ($CHCl_3$) 3354 (OH) and 1439 (P–Ph); δ_H (400 MHz; $CDCl_3$) 7.8–7.7 (4 H, m), 7.55–7.3 (12 H, m, Ph_2PO, Ph and remaining Ar), 6.35 (2 H, m, Ar), 5.24 (1 H, br d, *J* 8.7, C*H*OH), 5.01 (1 H, br s, OH), 4.44 (1 H, d, *J* 11.0, PhC$H_A H_B$), 4.02 (d, *J* 11.0, PhC$H_A H_B$), 3.13 (1 H, t, *J* 8.5, PCH), 2.9–2.75 (2 H, m), 1.7–1.2 (3 H, m) and 0.63 (3 H, t, *J* 7.5, Me); δ_C (100 MHz; $CDCl_3$) 154.4$^-$ (d, $^3J_{PC}$ 14.6, *ipso*-Ar), 140.7$^+$ (Ar), 139.2$^-$ (*ipso*-Ph), 133–127 (m, Ph_2PO and remaining Ph), 110.9$^+$ (Ar), 106.6$^+$ (Ar), 79.4$^+$ (d, $^3J_{PC}$ 68.6, *C*HOBn), 71.6$^-$ (Ph*C*H_2), 66.5$^+$ (CHOH), 38.0$^+$ (d, $^1J_{PC}$ 68.5, PCH), 26.2$^-$, 26.1$^-$ and 8.8$^+$ (Me); *m*/*z* 428.2 (55%, M^+), 201.1 (95, Ph_2PO) and 91.1 (100, Bn).

(1*S*,2*R*,4*R*)- and (1*R*,2*S*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)octan-1-ol 35b and 36b

By the same general method, (*R*)-1-diphenylphosphinoylheptan-3-yl benzyl ether **31b** (6.34 g, 15.6 mmol) and furfural (1.42 cm^3, 17.2 mmol) in THF gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to be a 75:25 ratio of **35b**:**36b**. Purification by flash chromatography eluting with 2:1 EtOAc–hexane gave the *alcohols* **35b** and **36b** (4.72 g, 61%, 82:18 ratio of diastereomers) as an oil. Further purification by HPLC eluting with chloroform gave the *alcohol* **35b** (2.54 mg, 33%) as an oil, retention time 15 min; R_f 0.56 (EtOAc); $[\alpha]_D^{20}$ +23.0 (*c* 0.80 in $CHCl_3$; 84% ee) (Found: MH^+, 503.2394. $C_{31}H_{35}O_4P$ requires *MH*, 503.2351); ν_{max}/cm^{-1} ($CHCl_3$) 3358 (OH) and 1438 (P–Ph); δ_H (400 MHz; $CDCl_3$) 7.77 (2 H, ddd, *J* 1.4, 7.7 and 9.5), 7.6–7.25 (14 H, m, Ph_2PO, Ph and remaining Ar), 6.38 (1 H, br d, *J* 3.3, Ar), 6.28 (1 H, dd, *J* 1.8 and 3.2, Ar), 5.24 (1 H, br d, *J* 10.2, C*H*OH), 4.82 (1 H, d, *J* 1.8, OH), 4.30 (1 H, d, *J* 12.1, PhC$H_A H_B$), 4.09 (1 H, d, *J* 12.1, PhC$H_A H_B$), 2.88 (1 H, m, PCH), 2.43 (1 H, m, C*H*OBn), 2.12 (1 H, dddd, *J* 3.9, 5.3, 13.2 and $^3J_{PH}$ 22.0, PCHC$H_A H_B$), 1.95 (1 H, dddd, *J* 4.3, 6.5, 15.3 and $^3J_{PH}$ 17.7, PCHCH$_A H_B$), 1.8–0.8 (6 H, m) and 0.76 (3 H, t, *J* 7.3, Me); δ_C (100 MHz; $CDCl_3$) 153.9$^-$ (d, $^3J_{PC}$ 13.8, *ipso*-Ar), 141.0$^+$ (Ar), 138.9$^-$ (*ipso*-Ph), 132–127 (m, Ph_2PO and Ph), 110.3$^+$ (Ar), 106.8$^+$ (Ar), 77.3$^+$ (d, $^3J_{PC}$ 4.1, *C*HOBn), 69.6$^-$ (Ph*C*H_2), 67.4$^+$ (CHOH), 38.0$^+$ (d, $^1J_{PC}$ 68.6, PCH), 32.8$^-$, 26.9$^-$, 26.7$^-$, 22.5$^-$ and 13.9$^+$ (Me); *m*/*z* (FAB) 503.2 (10%, MH^+), 229.1 (80), 202.1 (75, Ph_2POH) and 91.1 (100, Bn).

Also obtained was *alcohol* **36b** (0.40 g, 5%) as an oil, retention time 13 min; R_f 0.56 (EtOAc); $[\alpha]_D^{20}$ 0.0 (*c* 1.81 in $CHCl_3$; 84% ee) (Found: MH^+, 503.2392. $C_{31}H_{35}O_4P$ requires *M*, 503.2351); ν_{max}/cm^{-1} ($CHCl_3$) 3354 (C=O) and 1439 (P–Ph); δ_H (400 MHz; $CDCl_3$) 7.85–7.2 (16 H, m, Ph_2PO, Ph and remaining Ar), 6.34 (2 H, m, Ar), 5.21 (1 H, d, *J* 9.5, OH), 5.00 (1 H, m, C*H*OH), 4.44 (1 H, d, *J* 10.9, PhC$H_A H_B$), 4.04 (1 H, d, *J* 10.9, PhC$H_A H_B$), 3.12 (1 H, t, *J* 8.5, PCH), 2.30 (1 H, m, C*H*OBn), 2.21 (1 H, m), 1.7–0.8 (7 H, m) and 0.82 (3 H, t, *J* 7.3, Me); δ_C (100 MHz; $CDCl_3$) 154.5$^-$ (d, $^3J_{PC}$ 14.4, *ipso*-Ar), 140.6$^-$ (*ipso*-Ph), 133–127 (m, Ph_2PO and remaining Ph and Ar), 110.9$^+$ (Ar), 106.6$^+$ (Ar), 78.4$^+$ (d, $^3J_{PC}$ 9.4, *C*HOBn), 71.6$^-$ (Ph*C*H_2), 66.5$^+$ (CHOH), 38.0$^+$ (d, $^1J_{PC}$ 68.7, PCH), 33.5$^-$,

27.0$^-$, 26.8$^-$, 22.7$^-$ and 14.0$^+$ (Me); *m*/*z* 503.2 (50%, MH$^+$) and 202.1 (100, Ph_2POH).

Also obtained was a mixture of **35b** and **36b** (1.30 g, 17%, 73:27 mixture of diastereomers).

(1*S*,2*R*,4*S*)- and (1*R*,2*S*,4*S*)-4-Benzyloxy-4-cyclohexyl-2-diphenylphosphinoyl-1-(2-furyl)butan-1-ol 35c and 36c

By the same general method, (*S*)-3-diphenylphosphinoyl-1-cyclohexylpropyl benzyl ether **31c** (790 mg, 1.83 mmol) and furfural (181 µl, 2.21 mmol) in THF gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to be a 70:21:9 ratio of diastereomers. Purification by flash chromatography eluting with 2:1 EtOAc–hexane gave the *alcohols* **35c** and **36c** (786 mg, 82%, 78:22 mixture of diastereomers) as an oil, R_f 0.56 (EtOAc); $[\alpha]_D^{20}$ +10.8 (*c* 0.21 in $CHCl_3$; 89% ee) (Found: M$^+$, 528.2429. $C_{33}H_{37}O_4P$ requires *M*, 528.2430); ν_{max}/cm^{-1} ($CHCl_3$) 3445 (OH), 1423 (P–Ph) and 1210 (P=O); δ_H (400 MHz; $CDCl_3$) 7.75–7.2 (16 H, Ph_2PO, Ph and remaining Ar), 6.36 (1 H, m, Ar$^{maj\,+\,min}$), 6.24 (1 H, dd, *J* 1.8 and 3.2, Ar^{maj}), 6.08 (1 H, dd, *J* 1.9 and 3.2, Ar^{min}), 5.20 (1 H, br d, *J* 9.5, C*H*OH$^{maj\,+\,min}$), 5.04 (1 H, br s, OH^{min}), 4.80 (1 H, br s, OH^{maj}), 4.49 (1 H, d, *J* 11.9, PhC$H_AH_B^{min}$), 4.34 (1 H, d, *J* 12.2, PhC$H_AH_B^{maj}$), 4.11 (1 H, d, *J* 12.2, PhC$H_AH_B^{maj}$), 4.05 (1 H, d, *J* 11.8, PhC$H_AH_B^{min}$), 3.08 (1 H, t, *J* 8.2, PCH^{min}), 2.82 (1 H, m, PCH^{maj}) and 2.3–0.5 (13 H, m); δ_C (100 MHz; $CDCl_3$) 153.9$^-$ (d, $^3J_{PC}$ 13.4, *ipso*-Ar^{maj}), 139.2$^-$ (*ipso*-Ph^{min}), 139.1$^-$(*ipso*-Ph^{maj}), 133–127 (m, Ph_2PO and remaining Ar and Ph), 110.9$^+$ (Ar^{min}), 110.3$^+$ (Ar^{maj}), 106.9$^+$ (Ar^{maj}), 106.6$^+$ (Ar^{min}), 82.6$^+$ (d, $^3J_{PC}$ 10.3, Ph*C*HOBn^{min}), 80.4$^+$ (Ph*C*HOBn^{maj}), 72.6$^-$ (Ph*C*H$_2^{min}$), 70.3$^-$ (Ph*C*H$_2^{maj}$), 67.5$^+$ (CHOH^{maj}), 66.3$^+$ (CHOH^{min}), 40.7$^+$ (d, $^1J_{PC}$ 71.5, PCH^{min}), 38.2$^+$ (d, $^1J_{PC}$ 68.4, PCH^{maj}) and 30–22 (m); *m*/*z* 528.2 (80%, M$^+$), 201.0 (95, Ph_2PO) and 91.1 (100, Bn).

(3*R**,4*S**,6*S**)- and (3*R**,4*S**,6*R**)-6-Benzyloxy-4-diphenylphosphinoyl-2-methyloct-1-en-3-ol 35f and 36f

By the same general method, 1-diphenylphosphinoylpentan-3-yl benzyl ether **31a** (319 mg, 0.81 mmol) and methacrolein (74 µl, 0.91 mmol) in THF gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to be a 60:40 ratio of **35f** and **36f**. Purification by flash chromatography eluting with 1:1 EtOAc–hexane gave the *alcohols* **35f** and **36f** (129 mg, 35%, 60:40 mixture of diastereomers) as an oil, R_f 0.53 (EtOAc) (Found: M$^+$ − BnOCHEt, 299.1187. $C_{28}H_{33}O_3P$ requires *M* − *BnOCHEt*, 299.1201); ν_{max}/cm^{-1} ($CHCl_3$) 3358 (br OH), 1438 (P–Ph) and 1163 (P=O); δ_H (400 MHz; $CDCl_3$) 8.0–7.2 (15 H, m, Ph_2PO and Ph), 5.26 (1 H, br s, C=C$H_AH_B^{min}$), 5.23 (1 H, br s, C=C$H_AH_B^{maj}$), 4.99 (1 H, br s, C=C$H_AH_B^{maj}$), 4.91 (1 H, br s, C=C$H_AH_B^{min}$), 4.82 (1 H, br s, OH^{maj}), 4.77 (1 H, br s, OH^{min}), 4.55 (1 H, d, *J* 11.1, PhC$H_AH_B^{min}$), 4.50 (1 H, d, *J* 12.1, PhC$H_AH_B^{maj}$), 4.39 (1 H, d, *J* 11.6, C*H*OH^{maj}), 4.35 (1 H, d, *J* 11.4, C*H*OH^{min}), 4.24 (1 H, d, *J* 11.1, PhC$H_AH_B^{min}$), 4.05 (1 H, d, *J* 12.1, PhC$H_AH_B^{maj}$), 3.36 (1 H, m, min), 2.82 (1 H, t, *J* 8.1, PCH^{min}), 2.62 (1 H, q, *J* 8.0, PCH^{maj}), 2.4–1.2 (8 H, m), 0.77 (3 H, t, *J* 7.4, Me^{maj}) and 0.51 (3 H, t, *J* 7.1, Me^{min}); δ_C (100 MHz; $CDCl_3$) 143.5$^-$ (d, $^3J_{PC}$ 14.0, CH_2=*C*^{min}), 142.2$^-$ (d, $^3J_{PC}$ 13.2, CH_2=*C*^{maj}), 139.1$^-$ (*ipso*-Ph$^{maj\,+\,min}$), 133–127 (m, Ph_2PO and remaining Ph), 112.1$^-$ (*C*H$_2$=C^{maj}), 111.8$^-$ (*C*H$_2$=C^{min}), 79.5$^+$ (d, $^3J_{PC}$ 9.0, Ph*C*HOBn^{min}), 77.2$^+$ (CHOH^{maj}), 72.6$^+$ (d, $^3J_{PC}$ 2.2, Ph*C*HOBn^{maj}), 70.9$^+$ (CHOH^{min}), 70.7$^-$ (Ph*C*H$_2^{min}$), 69.7$^-$ (Ph*C*H$_2^{maj}$), 35.3$^+$ (d, $^1J_{PC}$ 69.6, PCH^{maj}), 35.2$^+$ (d, $^1J_{PC}$ 69.2, PCH^{min}), 25.0$^-$, 19.6$^-$ (min), 19.5$^-$ (maj), 8.9$^+$ (Me^{maj}) and 8.6$^+$ (Me^{min}); *m*/*z* 299.1 (4%, M$^+$ − BnOCHEt) and 201.1 (35, Ph_2PO).

(2*E*,4*R**,5*S**,7*S**)- and (2*E*,4*R**,5*S**,7*R**)-7-Benzyloxy-5-diphenylphosphinoyl-3-methylnon-2-en-4-ol 35e and 36e

By the same general method, 1-diphenylphosphinoylpentan-3-yl benzyl ether **31a** (43 mg, 0.11 mmol) and *trans*-2-methylbut-2-enal (15 µl, 0.14 mmol) in THF gave a crude product which was purified by flash chromatography eluting with 3:2 EtOAc–hexane to give the *alcohols* **35e** and **36e** (10 mg, 19%, 62:38 mixture of diastereomers) as an oil, R_f 0.53 (EtOAc) (Found: M$^+$, 462.2328. $C_{29}H_{37}O_3P$ requires *M*, 462.2324); ν_{max}/cm^{-1} ($CHCl_3$) 3362 (br OH), 1438 (P–Ph) and 1161 (P=O); δ_H (400 MHz; $CDCl_3$) 7.8–7.1 (15 H, m, Ph_2PO and Ph), 5.73 (1 H, q, *J* 6.9, MeC*H*=C^{maj}), 5.67 (1 H, q, *J* 6.9, MeC*H*=C^{min}), 4.51 (1 H, d, *J* 11.1 PhC$H_AH_B^{maj}$), 4.45 (1 H, d, *J* 12.0, PhC$H_AH_B^{min}$), 4.35 (1 H, br d, *J* 10.9, C*H*OH^{min}), 4.31 (1 H, br d, *J* 10.5, C*H*OH^{maj}), 4.19 (1 H, d, *J* 11.1, PhC$H_AH_B^{maj}$), 4.05 (1 H, d, *J* 12.0, PhC$H_AH_B^{min}$), 3.16 (1 H, m, C*H*OBn^{maj}), 2.77 (1 H, t, *J* 7.7, PCH^{maj}), 2.57 (1 H, m, min), 2.40 (1 H, m, min), 2.2–1.1 (4 H, m), 1.59 (3 H, d, *J* 6.8, Me$^{maj\,+\,min}$), 1.45 (3 H, s, Me^{min}), 1.38 (3 H, s, Me^{maj}), 0.77 (3 H, t, *J* 7.5, Me^{maj}) and 0.53 (3 H, t, *J* 7.5, Me^{min}); *m*/*z* 462.2 (20%, M$^+$) and 229 (100).

Also obtained was the *alcohol* **38e** (8 mg, 15%, >95:5 ratio of diastereomers) as an oil, R_f 0.40 (EtOAc) (Found: M$^+$, 462.2327. $C_{29}H_{37}O_3P$ requires *M*, 462.2324); ν_{max}/cm^{-1} ($CHCl_3$) 3362 (br OH), 1438 (P–Ph) and 1175 (P=O); δ_H (400 MHz; $CDCl_3$) 7.8–7.1 (15 H, m, Ph_2PO and Ph), 5.62 (1 H, q, *J* 5.3, CHO*H*), 5.47 (1 H, q, *J* 6.6, MeC*H*=C), 4.63 (1 H, d, *J* 11.0 PhCH_AH_B), 4.19 (1 H, d, *J* 11.0, PhCH_AH_B), 4.23 (1 H, m, C*H*OH), 3.41 (1 H, m, C*H*OBn), 3.05 (1 H, m, PCH), 1.7–1.4 (4 H, m), 1.38 (3 H, s, Me), 1.32 (1 H, d, *J* 6.6, Me) and 0.74 (3 H, t, *J* 7.5, Me); *m*/*z* 462.2 (25%, M$^+$) and 229 (100).

(3*R**,4*S**,6*S**)- and (3*R**,4*S**,6*R**)-4-Diphenylphosphinoyl-6-methoxymethoxy-2-methyloct-1-en-3-ol 35g and 36g

By the same general method, 1-diphenylphosphinoylpentan-3-yl methoxymethyl ether **32** (596 mg, 1.79 mmol) and methacrolein (0.58 cm^3, 1.98 mmol) in THF gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to be a 41:32:16:10 ratio of diastereomers. Purification by flash chromatography eluting with 1:1 EtOAc–hexane gave the *alcohols* **35g** and **36g** (275 mg, 38%, 55:45 mixture of diastereomers) as an oil, R_f 0.58 (EtOAc) (Found: MH$^+$, 403.2039. $C_{23}H_{31}O_5P$ requires *MH*, 403.2038); ν_{max}/cm^{-1} ($CHCl_3$) 3405 (br OH), 1654 (C=C), 1438 (P–Ph) and 1200 (P=O); δ_H (400 MHz; $CDCl_3$) 8.0–7.25 (10 H, m, Ph_2PO), 5.24 (1 H, br s, OH^{min}), 5.18 (1 H, br s, OH^{maj}), 4.96 (1 H, br s, C=C$H_AH_B^{min}$), 4.92 (1 H, br s, C=C$H_AH_B^{min}$), 4.86 (1 H, br s, C=C$H_AH_B^{maj}$), 4.75 (1 H, br s, C=C$H_AH_B^{maj}$), 4.52 (2 H, AB q, *J* 6.4, OCH_AH_BO^{min}), 4.48 (1 H, d, *J* 6.1, OCH_AH_BO^{maj}), 4.41 (1 H, d, *J* 10.6, C*H*OH^{maj}), 4.35 (1 H, d, *J* 10.6, C*H*OH^{min}), 4.32 (1 H, d, *J* 6.2, OCH_AH_BO^{maj}), 3.34 (3 H, s, OMe^{maj}), 3.32 (3 H, s, OMe^{min}), 3.30 (1 H m, C*H*OMOM^{maj}), 2.70 (1 H, m, 2.62 C*H*OMOM^{min}), 2.42 (1 H, m, PCH^{maj}), 2.20 (1 H, m, PCH^{min}), 2.0–1.0 (4 H, m), 1.64 (3 H, s, Me^{maj}), 1.60 (3 H, s, Me^{min}), 0.72 (3 H, t, *J* 7.6, Me^{min}) and 0.51 (3 H, t, *J* 7.5, Me^{maj}); δ_C (100 MHz; $CDCl_3$) 143.4$^-$ (d, $^3J_{PC}$ 13.9, CH_2=*C*^{min}), 142.7$^-$ (d, $^3J_{PC}$ 13.4, CH_2=*C*^{maj}), 133–128 (m, Ph_2PO), 112.1$^-$ (*C*H$_2$=C^{maj}), 111.8$^-$ (*C*H$_2$=C^{min}), 96.2$^-$ (OCH$_2$O^{maj}), 96.1$^-$ (OCH$_2$O^{min}), 79.6$^+$ (d, $^3J_{PC}$ 8.8, CH$_2$OMOM$^{maj/min}$), 79.6$^+$ (CH$_2$OMOM$^{min/maj}$), 72.6$^+$ (CHOH^{maj}), 71.1$^+$ (d, $^2J_{PC}$ 2.2, *C*HOH^{min}), 55.5$^+$ (OMe^{min}), 55.5$^+$ (OMe^{maj}), 35.3$^+$ (d, $^1J_{PC}$ 69.3, PCH$^{maj\,+\,min}$), 27.7$^-$ (maj), 27.4$^-$ (min), 25.7$^-$ (maj), 25.5$^-$ (min), 19.5$^+$ (Me^{min}), 19.5$^+$ (Me^{maj}), 9.4$^+$ (Me^{maj}) and 9.0$^+$ (Me^{min}); *m*/*z* (FAB) 403.2 (10%, MH$^+$), 229 (100) and 201.1 (60, Ph_2PO).

(1*R**,2*S**,4*R**)- and (1*R**,2*S**,4*S**)-4-Benzyloxy-2-diphenylphosphinoyl-1-phenylhexan-1-ol 36h and 35h

By the same general method, 1-diphenylphosphinoylpentan-3-yl benzyl ether **31a** (279 mg, 0.70 mmol) and benzaldehyde (83 µl, 0.81 mmol) in toluene with lithiation at −78 °C for 1 h gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to be a 25:51:19:6 ratio of **35h**:**36h**:**37h**:**38h**. Purification by flash chromatography, eluting with 1:1 EtOAc–hexane gave the *alcohols* **36h** and **35h** (164 mg, 65%, 74:26

mixture of diastereomers) as an oil, R_f 0.51 (EtOAc) (Found: $M^+ - BnH$, 392.1545. $C_{31}H_{33}O_3P$ requires $M - BnH$, 392.1541); ν_{max}/cm^{-1} ($CHCl_3$) 3364 (br OH), 1591 (Ph), 1438 (P–Ph) and 1160 (P=O); δ_H (400 MHz; $CDCl_3$) 7.9–6.9 (20 H, m, Ph_2PO and Ph × 2), 5.23 (1 H, d, J 10.1, C*H*OH$^{maj+min}$), 5.10 (1 H, br s, OH^{maj}), 4.86 (1 H, br s, OH^{min}), 4.23 (1 H, d, J 11.1, PhC$H_AH_B^{maj}$), 4.09 (1 H, d, J 12.1, PhC$H_AH_B^{min}$), 3.88 (1 H, d, J 12.1, PhC$H_AH_B^{min}$), 3.62 (1 H, d, J 11.1, PhC$H_AH_B^{maj}$), 2.92 (1 H, t, J 8.1, PCH^{maj}), 2.67 (1 H, m, PCH^{min}), 2.4–0.9 (4 H, m), 0.57 (3 H, t, J 7.4, Me^{maj}), 0.41 (3 H, t, J 7.4, Me^{min}); δ_C (100 MHz; $CDCl_3$) 142.5$^-$ (d, $^3J_{PC}$ 14.7, *ipso*-Ph^{maj}), 141.8$^-$ (d, $^3J_{PC}$ 13.8, *ipso*-Ph^{min}), 139.3$^-$, 139.2$^-$(*ipso*-Ph$^{maj+min}$), 133–125 (m, Ph_2PO and remaining 2 × Ph), 79.6$^+$ (d, $^3J_{PC}$ 9.1, Ph*C*HOBn^{maj}), 78.7$^+$ (d, $^3J_{PC}$ 3.5, Ph*C*HOBn^{min}), 71.3$^+$ (CHOH^{min}), 71.2$^-$ (Ph*C*H$_2^{maj}$), 69.8$^+$ (CHOH^{maj}), 69.3$^-$ (Ph*C*H$_2^{min}$), 40.5$^+$ (d, $^1J_{PC}$ 67.6, PCH$^{min+maj}$), 26.1$^-$ (maj), 25.8$^-$ (min), 25.4$^-$ (maj), 25.2$^-$ (min), 9.2$^+$ (Me^{min}) and 8.9$^+$ (Me^{maj}); *m*/*z* 392.1541 (80%, $M^+ - BnH$) and 229.1 (100).

(3*R**,4*S**,6*R**)- and (3*R**,4*S**,6*S**)-6-Benzyloxy-4-diphenylphosphinoyl-2-methyloct-1-en-3-ol 36f and 35f

By the same general method, 1-diphenylphosphinoylpentan-3-yl benzyl ether **31a** (312 mg, 0.79 mmol) and methacrolein (75 μl, 0.92 mmol) in toluene with lithiation at −78 °C for 1 h gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to be a 17:39:20:25 ratio of **35f**:**36f**:**37f**:**38f**. Purification by flash chromatography eluting with 1:1 EtOAc–hexane gave the *alcohols* **36f** and **35f** (118 mg, 33%, 71:29 mixture of diastereomers) as an oil, spectroscopically identical to that obtained previously.

Also obtained were the *alcohols* **37f** and **38f** (71 mg, 20%, >95:5 mixture of diastereomers) as an oil, R_f 0.24 (1:1 hexane–EtOAc); δ_H (400 MHz; $CDCl_3$) 8.8–7.2 (15 H, m, Ph_2PO and Ph), 5.64 (1 H, d, J 4.2, OH), 4.90 (1 H, br s, C=CH_AH_B), 4.63 (1 H, d, J 11.0, PhCH_AH_B), 4.30 (2 H, m, C=CH$_A$$H_B$ and PhCH$_A$$H_B$), 3.47 (1 H, m, C*H*OBn), 3.05 (1 H, m, PCH), 1.8–1.2 (7 H, m) and 1.05 (3 H, d, J 7.5, Me).

(1*R*,2*S*,4*R*)- and (1*S*,2*R*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-(4-methoxyphenyl)octan-1-ol 36d and 35d

By the same general method, (*R*)-1-diphenylphosphinoylheptan-3-yl benzyl ether **31b** (243 mg, 0.59 mmol) and *p*-anisaldehyde (90 μl, 0.72 mmol) in toluene with lithiation at −78 °C for 45 min gave a crude product. Purification by flash chromatography eluting with 3:2 EtOAc–hexane gave the *alcohols* **36b** and **35b** (120 mg, 38%, 56:44 ratio of diastereomers) as an oil, spectroscopically identical to that obtained previously.

(1*R*,2*S*,4*R*)- and (1*S*,2*R*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)octan-1-ol 36b and 35b

By the same general method, (*R*)-1-diphenylphosphinoylheptan-3-yl benzyl ether **31b** (320 mg, 0.79 mmol) and furfural (72 μl, 0.87 mmol) in toluene with lithiation at −78 °C for 30 min gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to be a 34:43:25 mixture of diastereomers. Purification by flash chromatography eluting with 2:1 EtOAc–hexane gave the *alcohols* **36b** and **35b** (224 mg, 57:43 ratio of diastereomers) as an oil, spectroscopically identical to that obtained previously.

(1*R**,2*S**,4*S**)- and (1*R**,2*S**,4*R**)-4-Benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)hexan-1-ol 35a and 36a

By the same general method, 1-diphenylphosphinoylpentan-3-yl benzyl ether **31a** (211 mg, 0.56 mmol) and furfural (55 μl, 0.66 mmol) in DME, with lithiation at −78 °C for 30 min, gave a crude product. Analysis of the crude product by ^{1}H NMR showed it to be a 57:19:11:13 ratio of **35a**:**36a**:**37a**:**38a**. Purification by flash chromatography eluting with 2:1 EtOAc–hexane gave the *alcohols* **35a** and **36a** (121 mg, 46%, 77:23 ratio of diastereomers) as an oil, spectroscopically identical to that obtained previously.

(2*S*,4*R*)- and (2*R*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-phenyloctan-1-one 44i and 45i

By the same general method, (*R*)-1-diphenylphosphinoylheptan-3-yl benzyl ether **31b** (1.03 g, 2.53 mmol) and ethyl benzoate (0.40 cm^3, 2.78 mmol) gave a crude product which was purified by flash chromatography eluting with 2:1 EtOAc–hexane, to give the *ketones* **44i** and **45i** (959 mg, 74%, 65:35 ratio of diastereomers) as an oil, R_f 0.48 (EtOAc); $[\alpha]_D^{20}$ +12.6 (*c* 0.70 in $CHCl_3$; 84% ee) (Found: $M^+ - Bu$, 453.1616. $C_{33}H_{35}O_3P$ requires $M^+ - Bu$, 453.1619); ν_{max}/cm^{-1} ($CHCl_3$) 1678 (C=O), 1434 (P–Ph) and 1220 (P=O); δ_H (400 MHz; $CDCl_3$) 7.9–7.1 (20 H, m, Ph_2PO and Ph × 2), 4.99 (1 H, ddd, J 1.9, 11.5 and $^2J_{PC}$ 13.9, PCH^{min}), 4.74 (1 H, ddd, J 3.0, 9.3 and $^2J_{PC}$ 16.2, PCH^{maj}), 4.46 (1 H, d, J 11.5, PhC$H_AH_B^{maj}$), 4.31 (1 H, d, J 11.7, PhC$H_AH_B^{min}$), 4.22 (1 H, d, J 11.7, PhC$H_AH_B^{min}$), 4.11 (1 H, d, J 11.5, PhC$H_AH_B^{maj}$), 3.41 (quin, J 6.1, C*H*OBn^{min}), 3.28 (1 H, m, C*H*OBn^{maj}), 2.65 (1 H, m, maj), 2.58 (1 H, m, min), 2.30 (1 H, m, min), 2.00 (1 H, m, maj), 1.7–1.1 (7 H, m), 0.82 (3 H, t, J 7.3, Me^{maj}) and 0.79 (3 H, t, J 7.2, Me^{min}); δ_C (63 MHz; $CDCl_3$) 197.6$^-$ (C=O$^{maj/min}$), 197.5$^-$ (C=O$^{min/maj}$), 138.6$^-$ (*ipso*-Ph^{min}), 138.4$^-$ (*ipso*-Ph^{maj}), 132–127 (m, Ph_2PO and remaining Ph), 78.1$^+$ (d, $^3J_{PC}$ 10.4, *C*HOBn^{min}), 77.2$^+$ (d, $^3J_{PC}$ 12.6, *C*HOBn^{maj}), 70.5$^-$ (Ph*C*H$_2^{maj}$), 70.4$^-$ (Ph*C*H$_2^{min}$), 48.3$^+$ (d, $^1J_{PC}$ 56.7, PCH^{min}), 46.9$^+$ (d, $^1J_{PC}$ 57.3, PCH^{maj}), 33.2$^-$, 33.1$^-$, 32.7$^-$, 32.3$^-$, 27.2$^-$ (min), 26.9$^-$ (maj), 22.7$^-$ (maj), 22.6$^-$ (min), 14.2$^+$ (Me^{maj}) and 14.0$^+$ (Me^{min}); *m*/*z* 453.2 (10%, M^+), 320.1 (80, $Ph_2POCHC(O)Ph$), 201.0 (100, Ph_2PO) and 105.0 (80, PhCO).

(2*S*,4*S*)- and (2*R*,4*S*)-4-Benzyloxy-1,4-diphenyl-2-diphenylphosphinoylbutan-1-one 44j and 45j

By the same general method, (*S*)-3-diphenylphosphinoyl-1-phenylpropyl benzyl ether **31d** (1.05 g, 2.45 mmol) and ethyl benzoate (0.42 cm^3, 2.6 mmol) in THF gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed it to be a 79:21 ratio of **44j** and **45j**. Purification by flash chromatography eluting with 3:2 EtOAc–hexane gave the *ketones* **44j** and **45j** (1.08 g, 82%, 80:20 mixture of diastereomers) as an oil, R_f 0.54 (EtOAc); $[\alpha]_D^{20}$ −3.9 (*c* 1.29 in $CHCl_3$; 100% ee) (Found: $M^+ - BnH$, 443.1407. $C_{35}H_{31}O_3P$ requires $M - BnH$, 443.1407); ν_{max}/cm^{-1} ($CHCl_3$) 1674 (C=O), 1438 (P–Ph) and 1182 (P=O); δ_H (400 MHz; $CDCl_3$) 7.8–7.1 (25 H, m, Ph_2PO and Ph × 3), 5.21 (1 H, ddd, J 2.1, 11.1 and 13.9, PCH^{maj}), 4.59 (1 H, ddd, J 2.7, 9.7 and 17.1, PCH^{min}), 4.34 (1 H, d, J 11.4 PhC$H_AH_B^{maj}$), 4.30 (1 H, m, C*H*OBn$^{maj+min}$), 4.24 (1 H, d, J 11.5, PhC$H_AH_B^{min}$), 4.04 (1 H, d, J 11.5, PhCH$_A$$H_B^{min}$), 4.02 (1 H, d, J 11.5, PhCH$_A$$H_B^{maj}$), 2.85 (1 H, m, min), 2.77 (1 H, m, maj), 2.4–2.2 (1 H, m, maj+min); δ_C (100 MHz; $CDCl_3$) 197.4$^-$ (C=O^{maj}), 197.0$^-$ (C=O^{min}), 141.2$^-$ (*ipso*-Ph^{maj}), 140.5$^-$ (*ipso*-Ph^{min}), 138.4$^-$, 138.0$^-$ (*ipso*-Ph^{maj}), 137.8$^-$, 137.7$^-$ (*ipso*-Ph^{min}), 132–126 (m, Ph_2PO and remaining 3 × Ph), 80.7$^+$ (d, $^3J_{PC}$ 10.6, Ph*C*HOBn^{min}), 79.0$^+$ (d, $^3J_{PC}$ 12.2, Ph*C*HOBn^{maj}), 70.6$^-$ (Ph*C*H$_2^{maj}$), 70.4$^-$ (Ph*C*H$_2^{min}$), 48.9$^+$ (d, $^1J_{PC}$ 56.2, PCH^{min}), 47.8$^+$ (d, $^1J_{PC}$ 57.0, PCH^{maj}) and 30.2$^-$ (maj + min); *m*/*z* 443.1 (10%, $M^+ - Bu$), 409.2 (55, $M^+ - Bn$), 201.0 (100, Ph_2PO) and 91.1 (75, Bn).

(2*S*,4*R*)- and (2*R*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)octan-1-one 44b and 45b

By the same general method, (*R*)-1-diphenylphosphinoylheptan-3-yl benzyl ether **31b** (781 mg, 1.92 mmol) and ethyl 2-furoate (0.29 cm^3, 2.11 mmol) gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed that it was a

72:28 mixture of **44b** and **45b**. Purification by flash chromatography eluting with 3:1 EtOAc–hexane gave the *ketones* **44b** and **45b** (575 mg, 60%, 63:37 ratio of diastereomers) as an oil, R_f 0.42 (EtOAc); $[\alpha]_D^{20}$ +13.3 (*c* 0.61 in $CHCl_3$; 84% ee) (Found: $M^+ - Bu$, 443.1407. $C_{31}H_{33}O_4P$ requires $M - Bu$, 443.1407); ν_{max}/cm^{-1} ($CHCl_3$) 1711 (C=O) and 1438 (P–Ph); δ_H (400 MHz; $CDCl_3$) 7.95–7.2 (15 H, m, Ph_2PO and Ph), 7.12 (1 H, m, Ar^{maj}), 7.10 (1 H, m, Ar^{min}), 6.93 (1 H, d, *J* 3.6, Ar^{maj}), 6.91 (1 H, d, *J* 3.6, Ar^{min}), 6.27 (1 H, dd, *J* 1.7 and 3.7, Ar^{maj}), 6.25 (1 H, dd, *J* 1.7 and 3.5, Ar^{min}), 4.80 (1 H, ddd, *J* 1.8, 11.6 and $^2J_{PH}$ 14.3, PCH^{maj}), 4.54 (1 H, ddd, *J* 1.4, 9.9 and $^2J_{PH}$ 14.3, PCH^{min}), 4.41 (1 H, d, *J* 11.4, $PhCH_AH_B^{maj}$), 4.34 (1 H, d, *J* 11.5, $PhCH_AH_B^{min}$), 4.21 (1 H, d, *J* 11.5, $PhCH_AH_B^{min}$), 4.18 (1 H, d, *J* 11.4, $PhCH_AH_B^{maj}$), 3.5–3.3 (2 H, m, PCH and C*H*OBn), 2.7–2.5 (1 H, m, maj + min), 2.22 (1 H, m, min), 1.95 (1 H, m, maj), 1.7–1.1 (7 H, m), 0.83 (3 H, t, *J* 7.3, Me^{maj}) and 0.79 (3 H, t, *J* 7.3, Me^{min}); δ_C (100 MHz; $CDCl_3$) 185.3$^-$ (C=O^{min}), 185.1$^-$ (C=O^{maj}), 153.2$^-$ (Ar^{maj}), 152.9$^-$ (Ar^{min}), 146.3$^-$ (Ar^{maj}), 146.1$^-$ (Ar^{min}), 138.6$^-$ (*ipso*-Ph^{maj}), 138.4$^-$ (*ipso*-Ph^{min}), 132–128 (m, Ph_2PO and remaining Ph), 117.8$^+$ (Ar^{maj}), 117.7$^+$ (Ar^{min}), 112.5$^+$ ($Ar^{maj\,+\,min}$), 78.4$^+$ (d, $^3J_{PC}$ 11.2, *C*HOBn^{maj}), 77.2$^+$ (*C*HOBn^{min}), 70.7$^-$ (Ph*C*H$_2^{maj}$), 70.4$^-$ (Ph*C*H$_2^{min}$), 49.0$^+$ (d, $^1J_{PC}$ 56.1, PCH^{min}), 47.1$^+$ (d, $^1J_{PC}$ 57.3, PCH^{maj}), 33.3$^-$ (maj), 33.1$^-$ (min), 31.6$^-$ (maj + min), 27.1$^-$ (maj + min), 22.7$^-$ (maj), 22.6$^-$ (min), 14.2$^+$ ($Me^{maj/min}$) and 14.0$^+$ ($Me^{min/maj}$); *m*/*z* 443.1 (25%, $M^+ - Bu$), 409.2 (55, $M^+ - Bn$), 201.0 (100, Ph_2PO) and 91.1 (75, Bn).

(2*S*,4*S*)- and (2*R*,4*S*)-4-Benzyloxy-4-cyclohexyl-2-diphenylphosphinoyl-1-(2-furyl)butan-1-one 44c and 45c

By the same general method, (*S*)-1-diphenylphosphinoyl-3-cyclohexylpropan-3-yl benzyl ether **31c** (812 mg, 1.88 mmol) and ethyl 2-furoate (0.31 cm^3, 2.31 mmol) gave a crude product. Analysis of the crude product by 400 MHz ^{1}H NMR showed that it was a 67:33 mixture of **44c** and **45c**. Purification by flash chromatography eluting with 2:1 EtOAc–hexane gave the *ketones* **44c** and **45c** (700 mg, 78%, 69:31 ratio of diastereomers) as an oil, R_f 0.44 (EtOAc); $[\alpha]_D^{20}$ +3.7 (*c* 1.47 in $CHCl_3$; 89% ee) (Found: $M^+ - C_6H_{11}$, 443.1405. $C_{33}H_{35}O_4P$ requires $M - C_6H_{11}$, 443.1412); ν_{max}/cm^{-1} ($CHCl_3$) 1715 (C=O), 1438 (P–Ph) and 1174 (P=O); δ_H (400 MHz; $CDCl_3$) 8.0–7.05 (16 H, m, Ph_2PO, Ph and remaining Ar), 6.92 (d, *J* 3.5, Ar^{maj}), 6.88 (1 H, dd, *J* 0.4 and 4.3, Ar^{min}), 6.29 (1 H, dd, *J* 1.6 and 3.6, Ar^{maj}), 6.21 (1 H, dd, *J* 1.9 and 3.6, Ar^{min}), 4.75 (1 H, ddd, *J* 1.6, 11.8 and $^2J_{PH}$ 19.7, PCH^{maj}), 4.46 (1 H, ddd, *J* 3.1, 9.4 and $^2J_{PH}$ 17.0, PCH^{min}), 4.42 (1 H, d, *J* 11.9, $PhCH_AH_B^{maj}$), 4.31 (1 H, d, *J* 11.2, $PhCH_AH_B^{min}$), 4.22 (1 H, d, *J* 12.4, $PhCH_AH_B^{min}$), 4.18 (1 H, d, *J* 11.6, $PhCH_AH_B^{maj}$), 3.24 (1 H, m, C*H*OBn^{min}), 3.11 (1 H, m, C*H*OBn^{maj}), 2.49 (1 H, m, PCH^{min}) and 2.3–0.8 (14 H, m); δ_C (50 MHz; $CDCl_3$) 185.3$^-$ (C=O), 152.8$^-$ (d, $^3J_{PC}$ 15.6, *ipso*-Ar), 138.8$^-$ (*ipso*-Ph), 132.5–127 (m, Ph_2PO and remaining Ph), 117.9$^+$ (Ar^{maj}), 117.8$^+$ (Ar^{min}), 112.5$^+$ ($Ar^{maj\,+\,min}$), 81.8$^+$ (d, $^3J_{PC}$ 12.0, *C*HOBn), 71.6$^-$ (Ph*C*H$_2^{maj}$), 71.1$^-$ (Ph*C*H$_2^{min}$), 47.2$^+$ (d, $^1J_{PC}$ 57.6, PCH^{min}) and 29–25 (m); *m*/*z* 443.2 (65%, $M - C_6H_{11}$), 310.1 (85), 201.1 (65, Ph_2PO) and 91.1 (100, Bn).

(1*S*,2*S*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)-octan-1-ol 37b

A solution of (1*R*,2*S*,4*R*)-4-benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)octan-1-ol **36b** (52 mg, 96 μmol, 86:14 mixture **36b**:**35b**) in dry dichloromethane (2 cm^3) was added to a stirred solution of Dess–Martin periodinane (55 mg, 0.15 mmol) in dry dichloromethane (2 cm^3) by cannula at 0 °C. The reaction was stirred for 30 min, warmed to room temperature, stirred for 1 h, diluted with dichloromethane (5 cm^3), quenched with saturated aqueous sodium thiosulfate solution (5 cm^3) and saturated aqueous sodium bicarbonate solution (5 cm^3), extracted with dichloromethane (3 × 5 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure to give a crude product which was mainly the *ketone* **44b** (85:15 mixture of diastereomers), R_f 0.59 (EtOAc); $[\alpha]_D^{20}$ +17.3 (*c* 0.30 in $CHCl_3$; 84% ee) (Found: MH^+, 541.2486. $C_{34}H_{37}O_4P$ requires *MH*, 541.2508); ν_{max}/cm^{-1} ($CHCl_3$) 1718 (C=O), 1422 (P–Ph) and 1201 (P=O); δ_H (400 MHz; $CDCl_3$) 8.0–7.1 (17 H, m, Ph_2PO, Ph and remaining Ar), 6.66 (2 H, br d, *J* 8.8, Ar), 4.97 (1 H, ddd, *J* 2.0, 11.4 and $^2J_{PH}$ 14.9, PCH^{maj}), 4.73 (1 H, ddd, *J* 2.9, 9.2 and $^2J_{PH}$ 17.1, PCH^{min}), 4.44 (1 H, d, *J* 11.4, $PhCH_AH_B^{maj}$), 4.31 (1 H, d, *J* 11.4, $PhCH_AH_B^{min}$), 4.23 (1 H, d, *J* 11.5, $PhCH_AH_B^{min}$), 4.09 (1 H, d, *J* 11.4, $PhCH_AH_B^{maj}$), 3.77 (3 H, s, OMe), 3.41 (1 H, quin, *J* 6.1, C*H*OBn^{min}), 3.28 (1 H, m, C*H*OBn^{maj}), 2.65–2.45 (1 H, m), 1.95 (1 H, m), 1.6–1.1 (6 H, m) and 0.83 (3 H, t, *J* 6.8, Me); *m*/*z* (FAB) 541.3 (70%, MH^+), 433.3 (50, M − OBn) and 307.1 (100). The crude product was dissolved in ethanol (3 cm^3), sodium borohydride (22 mg, 0.61 mmol) was added, the solution was stirred for 3 h, quenched with water (5 cm^3) and dilute hydrochloric acid until effervescence had finished and the solvent removed under reduced pressure. The residue was diluted 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 2:1 EtOAc–hexane to give the *alcohol* **37d** (38 mg, 73%, 87:13 mixture of diastereomers) as an oil, R_f 0.54 (EtOAc); $[\alpha]_D^{20}$ +4.4 (*c* 0.09 in $CHCl_3$; 84% ee) (Found: MH^+, 543.2694. $C_{34}H_{39}O_4P$ requires *M*, 543.2664); ν_{max}/cm^{-1} ($CHCl_3$) 3456 (OH), 1423 (P–Ph) and 1206 (P=O); δ_H (200 MHz; $CDCl_3$) 7.75–7.13 (15 H, m, Ph_2PO, Ph), 7.10 (2 H, d, *J* 8.7, $Ar^{maj\,+\,min}$), 6.66 (2 H, br d, *J* 8.7, Ar^{maj}), 6.59 (2 H, br d, *J* 8.7, Ar^{min}), 5.94 (1 H, d, *J* 4.4, OH^{maj}), 5.55 (1 H, d, *J* 7.1, OH^{min}), 5.01 (1 H, ddd, *J* 5.4, 6.5 and $^2J_{PH}$ 19.6, C*H*OH^{min}), 4.93 (1 H, ddd, *J* 4.5, 7.0 and $^2J_{PH}$ 16.3, C*H*OH^{maj}), 4.46 (1 H, d, *J* 11.1, $PhCH_AH_B^{maj}$), 4.36 (1 H, d, *J* 11.8, $PhCH_AH_B^{min}$), 4.14 (1 H, d, *J* 11.1, $PhCH_AH_B^{maj}$), 4.12 (1 H, d, *J* 11.8, $PhCH_AH_B^{min}$), 3.73 (3 H, s, OMe^{maj}), 3.68 (3 H, s, OMe^{min}), 3.15 (1 H, m C*H*OBn), 2.68 (1 H, m, PCH^{min}), 2.60 (1 H, m, PCH^{maj}), 1.6–0.8 (8 H, m), 0.79 (3 H, t, *J* 7.2, Me^{maj}) and 0.78 (3 H, t, *J* 7.2, Me^{min}); δ_C (50 MHz; $CDCl_3$) 158.9$^-$ (*ipso*-Ar^{maj}), 158.8$^-$ (*ipso*-Ar^{min}), 138.8$^-$ (*ipso*-Ph^{maj}), 138.7$^-$ (*ipso*-Ph^{min}), 134–127.5 (m, Ph_2PO and remaining Ar and Ph), 113.5$^+$ (Ar^{maj}), 113.3$^+$ (Ar^{min}), 77.3$^+$ (min), 76.6$^+$ (maj), 75.9$^+$ (min), 74.2$^+$ (d, $^3J_{PC}$ 3.3, *C*HOBn), 71.1$^-$ (PhC-H$_2^{maj}$), 70.2$^-$ (PhCH$_2^{min}$), 55.2$^+$, 55.2$^+$ ($OMe^{maj\,+\,min}$), 41.6$^+$ (d, $^1J_{PC}$ 67.4, PCH^{min}), 40.3$^+$ (d, $^1J_{PC}$ 66.9, PCH^{maj}), 33.4$^-$ (maj), 32.7$^-$ (min), 31.9$^-$ (maj), 31.6$^-$ (min), 26.9$^-$ (min), 26.8$^-$ (maj), 22.8$^-$ (maj), 22.7$^-$ (min) and 13.6$^+$ ($Me^{maj\,+\,min}$); *m*/*z* 542.3 (5%, M^+), 201.0 (70, Ph_2PO) and 91 (100, Bn).

(1*R*,2*R*,4*R*)- and (1*S*,2*S*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-(4-methoxyphenyl)octan-1-ol 38d

By the same general method, (1*S*,2*R*,4*R*)-4-benzyloxy-2-diphenylphosphinoyl-1-(4-methoxyphenyl)octan-1-ol **35d** (1.10 g, 2.03 mmol) and Dess–Martin periodinane (1.17 g, 3.05 mmol) gave a crude product which was the *ketone* **45d** , spectroscopically identical to the minor isomer obtained earlier, δ_C (50 MHz; $CDCl_3$) 195.5$^-$ (C=O), 163.2$^-$ (*ipso*-Ar), 138.4$^-$ (*ipso*-Ph), 133–127 (m, Ph_2PO and remaining Ar), 113.3$^+$ (Ar), 78.1$^+$ (d, $^3J_{PC}$ 24.4, *C*HOBn), 70.3$^-$ ($PhCH_2$), 55.3$^+$ (OMe), 47.5$^+$ (d, $^1J_{PC}$ 57.5, PCH), 33.0$^-$, 32.4$^-$, 27.1$^-$, 22.5$^-$ and 13.6$^+$ (Me). The crude product was dissolved in ethanol (40 cm^3), sodium borohydride (354 mg, 9.31 mmol) added, stirred for 3 h, quenched with water (50 cm^3) and dilute hydrochloric acid until effervescence had finished and the solvent removed under reduced pressure. The residue was diluted with water (100 cm^3), extracted with dichloromethane (3 × 60 cm^3), dried ($MgSO_4$) and evaporated to give a crude product which was purified by flash chromatography eluting with 2:1 EtOAc–hexane to give the *alcohols* **38d** and **37d** (803 mg, 69%, 51:49 mixture of diastereomers) as an oil, spectroscopically identical to that obtained previously.

(1*R*,2*R*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)-octan-1-ol 38b

By the same general method, (1*S*,2*R*,4*R*)-4-benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)octan-1-ol **35b** (80 mg, 0.16 mmol) and Dess–Martin periodinane (203 mg, 0.48 mmol) gave a crude product which was dissolved in ethanol (5 cm^3) and cooled to 0 °C. Sodium borohydride (24 mg, 0.64 mmol) added in one portion, the reaction mixture was stirred for 2 h, quenched with water (10 cm^3) and dilute hydrochloric acid added until effervescence had finished. The solvent was removed under reduced pressure the residue diluted 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 2:1 EtOAc–hexane to give the *alcohol* **38b** (66 mg, 83%) as an oil, R_f 0.59 (EtOAc); $[\alpha]_D^{20}$ +10.3 (*c* 0.21 in $CHCl_3$; 84% ee) (Found: MH^+, 503.2391. $C_{29}H_{31}O_4P$ requires *MH*, 503.2351); ν_{max}/cm^{-1} ($CHCl_3$) 3385 (OH), 1438 (P–Ph) and 1206 (P=O); δ_H (200 MHz; $CDCl_3$) 7.6–7.3 (15 H, m, Ph_2PO and Ph), 7.08 (1 H, d, *J* 1.1, Ar), 6.16 (1 H, d, *J* 3.2, Ar), 6.01 (1 H, dd, *J* 1.8 and 3.2, Ar), 5.42 (1 H, br s, OH), 5.08 (1 H, dd, *J* 5.1 and $^3J_{PH}$ 18.7, C*H*OH), 4.49 (1 H, d, *J* 12.0, $PhCH_AH_B$), 4.25 (1 H, d, *J* 12.0, $PhCH_AH_B$), 3.00 (1 H, quin, *J* 5.1, C*H*OBn), 2.71 (1 H, qd, *J* 5.5 and $^2J_{PH}$ 8.0, PCH), 2.1–1.8 (2 H, m), 1.5–0.9 (6 H, m) and 0.79 (3 H, t, *J* 7.3, Me); δ_C (100 MHz; $CDCl_3$) 154.3$^-$ (d, $^3J_{PC}$ 5.6, Ar), 138.7$^-$ (*ipso*-Ph), 133–127 (m, Ph_2PO and remaining Ar and Ph), 110.2$^+$ (Ar), 107.7$^+$ (Ar), 77.0$^+$ (CHOH), 70.2$^+$ (d, $^3J_{PC}$ 9.2, *C*HOBn), 70.2$^-$ ($PhCH_2$), 39.2$^+$ (d, $^1J_{PC}$ 68.7, PCH), 32.8$^-$, 30.9$^-$, 26.9$^-$, 22.7$^-$ and 13.9$^+$ (Me); *m*/*z* (FAB) 503.2 (80%, MH^+) and 201.0 (100, Ph_2PO).

In a separate experiment, (1*S*,2*R*,4*R*)-4-benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)octan-1-ol **35b** (620 mg, 1.23 mmol) gave, with addition of sodium borohydride over 30 min, the *alcohols* **38b** and **37b** (490 mg, 80% over 2 steps) as a 81:19 mixture of diastereomers. Purification by HPLC, eluting with chloroform, gave the *alcohol* **38b** (325 mg, 53% over 2 steps) as an oil, retention time 13.5 min, spectroscopically identical to that obtained previously.

(1*R*,2*R*,4*S*)-4-Benzyloxy-4-cyclohexyl-2-diphenylphosphinoyl-1-(2-furyl)butan-1-ol 38c

By the same general method, (1*S*,2*R*,4*S*)-4-benzyloxy-4-cyclohexyl-2-diphenylphosphinoyl-1-(2-furyl)octan-1-ol **35c** (600 mg, 1.15 mmol, 78:22 mixture of **35c** and **36c**) and Dess–Martin periodinane (1.46 mg, 3.45 mmol) gave a crude product which was dissolved in ethanol (30 cm^3) and cooled to 0 °C. Sodium borohydride (350 mg, 9.2 mmol) was added over 30 min, the reaction mixture was stirred for 2 h, quenched with water (30 cm^3) and dilute hydrochloric acid added until effervescence had finished. The solvent was removed under reduced pressure, the residue diluted with water (30 cm^3), extracted with dichloromethane (3 × 30 cm^3), dried ($MgSO_4$) and evaporated to give a crude product which was purified by flash chromatography eluting with 2:1 EtOAc–hexane to give the *alcohol* **38c** (537 mg, 90%, 75:25 mixture of diastereomers) as an oil, spectroscopically identical to that obtained previously, $[\alpha]_D^{20}$ +5.9 (*c* 0.29 in $CHCl_3$; 84% ee).

(1*S*,2*S*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)-octan-1-ol 37b

(2*S*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)octan-1-one **44b** (1.93 g, 0.16 mmol, 72:28 mixture of diastereomers) was dissolved in ethanol (200 cm^3), sodium borohydride (1.05 g, 30.7 mmol) added, stirred for 3 h, quenched with water (100 cm^3) and dilute hydrochloric acid added until effervescence had finished and the solvent removed under reduced pressure. The residue was diluted with water (200 cm^3), extracted with dichloromethane (3 × 200 cm^3), dried ($MgSO_4$) and evaporated to give a crude product which was purified by flash chromatography eluting with 2:1 EtOAc–hexane to give the *alcohols* **37b** and **38b** (1.87 g, 97%, 63:37 mixture) as an oil. Purification by HPLC, eluting with chloroform, gave the *alcohol* **37b** (1.46 g, 76%, 90:10 ratio of **37b**:**38b**) as an oil, retention time 12.5 min; R_f 0.52 (EtOAc); $[\alpha]_D^{20}$ +4.8 (*c* 0.46 in $CHCl_3$; 84% ee) (Found: M^+, 502.2268. $C_{29}H_{31}O_4P$ requires *M*, 502.2273); ν_{max}/cm^{-1} ($CHCl_3$) 3324 (OH), 1438 (P–Ph) and 1192 (P=O); δ_H (200 MHz; $CDCl_3$) 7.8–7.1 (16 H, m, Ph_2PO, Ph and remaining Ar), 6.18 (1 H, d, *J* 3.3, Ar), 6.06 (1 H, dd, *J* 1.8 and 3.2, Ar), 6.02 (1 H, d, *J* 6.2, OH), 5.03 (1 H, td, *J* 6.1 and $^3J_{PH}$ 18.7, C*H*OH), 4.55 (1 H, d, *J* 11.0, $PhCH_AH_B$), 4.36 (1 H, d, *J* 11.0, $PhCH_AH_B$), 3.42 (1 H, m, C*H*OBn), 2.95 (1 H, m, PCH), 1.8–1.05 (8 H, m) and 0.83 (3 H, t, *J* 6.8, Me); δ_C (100 MHz; $CDCl_3$) 154.3$^-$ (d, $^3J_{PC}$ 8.4, Ar), 138.7$^-$ (*ipso*-Ph), 132.5–127.5 (m, Ph_2PO and remaining Ar and Ph), 110.4$^+$ (Ar), 107.8$^+$ (Ar), 76.6$^+$ (d, $^3J_{PC}$ 11.0, *C*HOBn), 71.5$^-$ ($PhCH_2$), 68.9$^+$ (CHOH), 37.8$^+$ (d, $^1J_{PC}$ 67.9, PCH), 33.6$^-$, 31.5$^-$, 26.9$^-$, 22.8$^-$ and 14.0$^+$ (Me); *m*/*z* 502.2 (10, M^+), 202.1 (60, Ph_2POH) and 91.1 (100, Bn).

Also obtained was the *alcohol* **38b** (404 mg, 21%, >97:3 ratio of diastereomers), retention time 14 min, spectroscopically identical to that obtained previously.

(1*S*,2*S*,4*S*)-4-Benzyloxy-4-cyclohexyl-2-diphenylphosphinoyl-1-(2-furyl)butan-1-ol 37c

By the same general method, (2*S*,4*S*)-4-benzyloxy-4-cyclohexyl-2-diphenylphosphinoyl-1-(2-furyl)butan-1-one **44c** (640 mg, 1.21 mmol, 69:31 mixture of **44c**:**45c**) and sodium borohydride (92 mg, 2.42 mmol), with addition of the sodium borohydride over 10 min at 0 °C, gave a crude product which was purified by flash chromatography eluting with 2:1 EtOAc–hexane to give the *alcohols* **37c** and **38c** (454 g, 71%, 71:29 mixture of diastereomers) as an oil, R_f 0.50 (EtOAc); $[\alpha]_D^{20}$ +5.0 (*c* 0.38 in $CHCl_3$; 89% ee) (Found: M^+, 528.2430. $C_{33}H_{37}O_4P$ requires *M*, 528.2429); ν_{max}/cm^{-1} ($CHCl_3$) 3368 (OH), 1438 (P–Ph) and 1204 (P=O); δ_H (400 MHz; $CDCl_3$) 7.75–7.15 (15 H, m, Ph_2PO and Ph), 7.12 (1 H, dd, *J* 0.9 and 1.7, Ar^{maj}), 7.00 (1 H, d, *J* 0.9, Ar^{min}), 6.16 (1 H, d, *J* 3.2, Ar^{maj}), 6.08 (1 H, d, *J* 3.2, Ar^{min}), 6.06 (1 H, dd, *J* 1.8 and 3.2, Ar^{maj}), 6.01 (1 H, d, *J* 5.7, OH^{maj}), 5.89 (1 H, dd, *J* 1.8 and 3.2, Ar^{min}), 5.62 (1 H, d, *J* 8.5, OH^{min}), 5.0 (1 H, m, C*H*OH), 4.59 (1 H, d, *J* 11.0, $PhCH_AH_B{}^{maj}$), 4.52 (1 H, d, *J* 12.1, $PhCH_AH_B{}^{min}$), 4.39 (1 H, d, *J* 11.0, $PhCH_AH_B{}^{maj}$), 4.29 (1 H, d, *J* 12.1, $PhCH_AH_B{}^{min}$), 3.38 (1 H, m, C*H*OBn^{maj}), 2.82 (1 H, m, C*H*OBn^{min}), 2.68 (1 H, m, PCH^{maj}), 2.60 (1 H, m, PCH^{min}) and 2.2–0.5 (13 H, m); δ_C (50 MHz; $CDCl_3$) 154.5$^-$ (d, $^3J_{PC}$ 4.1, *ipso*-Ar^{min}), 154.2$^-$ (d, $^3J_{PC}$ 8.6, *ipso*-Ar^{maj}), 138.9$^-$ (*ipso*-Ph^{min}), 138.8$^-$ (*ipso*-Ph^{maj}), 133–126 (m, Ph_2PO, Ph and remaining Ar), 110.3$^+$ (Ar^{maj}), 109.9$^+$ (Ar^{min}), 107.6$^+$ (Ar^{maj}), 107.3$^+$ (Ar^{min}), 81.4$^+$ (d, $^3J_{PC}$ 9.6, *C*HOBn^{min}), 80.8$^+$ (d, $^3J_{PC}$ 9.6, *C*HOBn^{maj}), 72.5$^-$ ($PhCH_2{}^{maj}$), 71.1$^+$ (CHO-H^{min}), 70.6$^-$ ($PhCH_2{}^{min}$), 68.9$^+$ (CHOH^{maj}), 38.2$^+$ (d, $^1J_{PC}$ 67.5, PCH^{min}), 37.7$^+$ (d, $^1J_{PC}$ 67.6, PCH^{maj}) and 30–25 (m); *m*/*z* 528.2 (90%, M^+), 201.0 (95, Ph_2PO) and 91.1 (100, Bn).

(1*S*,2*S*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-phenyloctan-1-ol 37i

By the same general method, (2*S*,4*R*)-4-benzyloxy-2-diphenylphosphinoyl-1-phenyloctan-1-one **44i** (476 mg, 0.93 mmol, 65:35 mixture of **44i** and **45i**) and sodium borohydride (283 mg, 7.4 mmol), with addition of the sodium borohydride over 20 min at 0 °C, gave a crude product which was purified by flash chromatography eluting with 2:1 EtOAc–hexane to give the *alcohols* **37i** and **38i** (216 g, 46%, 70:30 mixture of diastereomers) as an oil, R_f 0.45 (EtOAc); $[\alpha]_D^{20}$ +10.4 (*c* 0.38 in $CHCl_3$; 84% ee) (Found: MH^+, 513.2543. $C_{33}H_{37}O_3P$ requires *MH*, 513.2558); ν_{max}/cm^{-1} ($CHCl_3$) 3347 (OH), 1438 (P–Ph) and 1211 (P=O); δ_H (200 MHz; $CDCl_3$) 7.8–7.0 (20 H, m, Ph_2PO and 2 × Ph), 6.07 (1 H, d, *J* 4.5, OH^{maj}), 5.70 (1 H, d, *J* 6.3, OH^{min}),

5.06 (1 H, ddd, *J* 5.5, 6.9 and $^3J_{PH}$ 16.3, C*H*OH^{min}), 4.92 (1 H, ddd, *J* 4.5, 7.1 and $^3J_{PH}$ 16.3, C*H*OH^{maj}), 4.44 (1 H, d, *J* 11.1, PhCH_AH$_B{}^{maj}$), 4.32 (1 H, d, *J* 11.9, PhCH_AH$_B{}^{min}$), 4.11 (1 H, m, PhCH$_A H_B{}^{maj+min}$), 3.21 (1 H, m, C*H*OBn$^{maj+min}$), 2.78 (1 H, m, PCH^{min}), 2.51 (1 H, m, PCH^{maj}) and 2.3–0.9 (8 H, m) and 0.79 (3 H, t, *J* 7.0, Me$^{maj+min}$); δ_C (50 MHz; $CDCl_3$) 142.4$^-$ (*ipso*-Ph^{min}), 142.3$^-$ (*ipso*-Ph^{maj}), 139.8$^-$ (*ipso*-Ph^{maj}), 138.7$^-$ (*ipso*-Ph^{min}), 132–126.5 (m, Ph_2PO and remaining 2 × Ph), 77.4$^+$ (m, min), 76.7–76.6$^+$ (m, maj+min), 74.8$^+$ (d, $^3J_{PC}$ 3.3, *C*HOBn^{maj}), 71.2$^-$ (PhCH$_2{}^{maj}$), 70.4$^-$ (PhCH$_2{}^{min}$), 41.3$^+$ (d, $^1J_{PC}$ 66.9, PCH^{min}), 40.0$^+$ (d, $^1J_{PC}$ 66.9, PCH^{maj}), 33.4$^-$ (maj), 32.6$^-$ (min), 32.0$^-$ (maj), 31.8$^-$ (min), 26.9$^-$, 26.8$^-$, 22.8$^-$, 22.7$^-$, 14.3$^+$ and 14.0$^+$ (Me); *m*/*z* (FAB) 513.3 (60, MH$^+$), 229.1 (75), 201.0 (Ph_2PO) and 91.1 (100, Bn).

(1*S*,2*S*,4*S*)- and (1*R*,2*R*,4*S*)-4-Benzyloxy-1,4-diphenyl-2-diphenylphosphinoylbutan-1-ol 37j

By the same general method, ketones **44j** and **45j** (338 mg, 0.66 mmol, 80:20 mixture) and sodium borohydride (50 mg, 1.32 mmol) with slow addition of the sodium borohydride over 20 min at 0 °C gave the *alcohols* **37j** and **38j** (315 mg, 93%, 72:28 mixture of diastereomers) as an oil, R_f 0.46 (EtOAc); $[\alpha]_D^{20}$ +264 (*c* 2.14 in $CHCl_3$; 100% ee) (Found: M$^+$, 532.2156. $C_{35}H_{33}O_3P$ requires *M*, 532.2167); ν_{max}/cm^{-1} ($CHCl_3$) 3344 (br, OH), 1438 (P–Ph) and 1195 (P=O); δ_H (400 MHz; $CDCl_3$) 7.9–7.1 (25 H, m, Ph_2PO and Ph × 3), 6.26 (1 H, d, *J* 2.6, OH^{maj}), 5.86 (1 H, d, *J* 5.7, OH^{min}), 5.08 (1 H, td, *J* 5.8 and 17.7, C*H*OH^{min}), 4.99 (1 H, ddd, *J* 2.6, 8.4 and 12.9, C*H*OH^{maj}), 4.21 (1 H, d, *J* 11.0 PhCH_AH$_B{}^{maj}$), 3.81 (d, *J* 11.6, PhCH_AH$_B{}^{min}$), 3.92 (1 H, d, *J* 11.0, PhCH_AH$_B{}^{maj}$), 3.81 (d, *J* 11.6, PhCH_AH$_B{}^{min}$), 3.55 (1 H, td, *J* 8.7 and 13.2, PCH^{maj}), 3.05 (1 H, m, CHOBn^{maj}) and 2.0–1.8 (2 H, m); δ_C (100 MHz; $CDCl_3$) 142.6$^-$ (*ipso*-Ph^{maj}), 142.4$^-$ (*ipso*-Ph^{min}), 142.3$^-$ (*ipso*-Ph^{min}), 141.7$^-$ (*ipso*-Ph^{maj}), 140.7$^-$ (*ipso*-Ph^{min}), 138.7$^-$ (*ipso*-Ph^{maj}), 133–126 (m, Ph_2PO and remaining 3 × Ph), 80.4$^+$ (d, $^3J_{PC}$ 9.0, CHOBn^{min}), 79.3$^+$ (d, $^3J_{PC}$ 9.1, CHOBn^{maj}), 76.2$^+$ (d, $^2J_{PC}$ 2.0, CHOBn^{min}), 75.1$^+$ (d, $^3J_{PC}$ 2.2, CHOBn^{maj}), 70.7$^-$ (CH_2Ph^{maj}), 70.3$^+$ (CH_2OBn^{min}), 41.0$^+$ (d, $^1J_{PC}$ 67.2, PCH^{min}), 40.8$^+$ (d, $^1J_{PC}$ 66.7, PCH^{maj}), 35.8$^-$ (maj) and 35.5$^-$ (maj); *m*/*z* 532.2 (30%, M$^+$) and 229.1 (100).

(1*Z*,4*R*)-1-(2-Furyl)oct-1-en-4-yl benzyl ether 49a

(1*R*,2*S*,4*R*)-4-Benzyloxy-2-diphenylphosphinoyl-1-(2-furyl)-octan-1-ol **35b** (463 mg, 0.92 mmol, 82:18 mixture **35b**:**36b**) in DMF (6 cm^3) was added dropwise by cannula to a stirred suspension of sodium hydride (55 mg of a 60% dispersion in oil, 1.38 mmol) in DMF (12 cm^3) at 20 °C. The reaction mixture was heated at 60 °C for 45 min, poured into saturated ammonium chloride solution (15 cm^3), extracted with dichloromethane (3 × 10 cm^3), and the combined organic fractions washed with water (3 × 25 cm^3), dried ($MgSO_4$) and evaporated to give a crude product which was purified by flash chromatography eluting with 30:1 hexane–EtOAc to give the *alkene* (*Z*)-**49a** (140 mg, 49%) as a liquid, R_f 0.30 (30:1 hexane–EtOAc); $[\alpha]_D^{20}$ −2.5 (*c* 0.9 in $CHCl_3$; 84% ee) (Found: BnOCHBu$^+$, 177.1274. $C_{19}H_{24}O_2$ requires *BnOCHBu*, 177.1279); ν_{max}/cm^{-1} ($CHCl_3$) 1603 (C=C); δ_H (400 MHz; $CDCl_3$) 7.45–7.25 (6 H, m, Ph and remaining Ar), 6.42 (1 H, dd, *J* 1.9 and 3.3, Ar), 6.30 (2 H, m, Ar and C*H*=CHCH$_2$), 5.70 (1 H, td, *J* 7.3 and 11.9, CH=C*H*CH$_2$), 4.63 (1 H, d, *J* 11.6, PhCH_AH$_B$), 4.55 (1 H, d, *J* 11.6, PhCH$_A H_B$), 3.60 (1 H, quin, *J* 5.8, C*H*OBn), 2.80 (2 H, m, CH=CHCH_2), 1.8–1.3 (6 H, m) and 0.93 (3 H, t, *J* 7.3, Me); δ_C (100 MHz; $CDCl_3$) 153.4$^-$ (*ipso*-Ar), 141.4$^-$ (*ipso*-Ph), 128.3$^+$, 127.8$^+$, 127.4$^+$, 120.6$^+$, 118.6$^+$, 111.1$^+$ (Ar), 109.2$^+$ (Ar), 78.8$^+$ (*C*HOBn), 70.9$^-$ (Ph*C*H$_2$), 33.9$^-$, 33.6$^-$, 27.7$^-$, 22.9$^-$ and 14.2$^+$ (Me); *m*/*z* 177.1 (60, BnOCHBu) and 91.1 (100, Bn).

(1*Z*,4*R*)-1-(4-Methoxyphenyl)oct-1-en-4-yl benzyl ether 49b

By the same general method, (1*S*,2*R*,4*R*)-4-benzyloxy-2-diphenylphosphinoyl-1-(4-methoxyphenyl)octan-1-ol **36d** (320 mg, 0.59 mmol, 72:28 mixture of **36d** and **36d**) and sodium hydride (35 mg of a 60% dispersion in oil, 0.89 mmol) gave a crude product which was purified by flash chromatography eluting with 4:1 hexane–EtOAc to give the *alkene* (*Z*)-**49b** (57 mg, 30%) as a liquid, R_f 0.79 (1:1 EtOAc–hexane); $[\alpha]_D^{20}$ +25.1 (*c* 1.00 in $CHCl_3$; 84% ee) (Found: M$^+$, 324.2090. $C_{22}H_{28}O_2$ requires *M*, 324.2089); ν_{max}/cm^{-1} ($CHCl_3$) 1607 (C=C); δ_H (400 MHz; $CDCl_3$) 7.35 (4 H, m, Ph), 7.28 (1 H, m, Ph), 7.24 (2 H, d, *J* 11.7, Ar), 6.89 (2 H, d, *J* 11.7, Ar), 6.45 (1 H, br d, *J* 11.7, C*H*=CHCH$_2$), 5.69 (1 H, td, *J* 7.2 and 11.7, CH=C*H*CH$_2$), 4.56 (1 H, d, *J* 11.6, PhCH_AH$_B$), 4.49 (1 H, d, *J* 11.6, PhCH$_A H_B$), 3.81 (3 H, s, OMe), 3.51 (1 H, quin, *J* 6.0, C*H*OBn), 2.60 (2 H, m, CH=CHCH_2), 1.55 (2 H, m), 1.45–1.2 (4 H, m) and 0.89 (3 H, t, *J* 7.2, Me); δ_C (100 MHz; $CDCl_3$) 158.2$^-$ (*ipso*-Ar), 138.9$^-$ (*ipso*-Ph), 130.3$^-$, 129.9$^+$, 129.8$^+$, 128.3$^+$, 127.7$^+$, 127.1$^+$, 113.6$^+$ (Ar), 78.9$^+$ (*C*HOBn), 70.9$^-$ (Ph*C*H$_2$), 55.2$^+$ (OMe), 33.7$^-$, 32.9$^-$, 29.5$^-$, 22.8$^-$ and 14.0$^+$ (Me); *m*/*z* 324.2 (30%, M$^+$) and 91.1 (100, Bn). Also obtained was *p*-anisaldehyde (18 mg, 23%).

(1*R*,3*Z*)-1,4-Diphenylbut-3-en-1-yl benzyl ether 49c

By the same general method, (1*S*,3*R*,4*S*)-1,4-diphenyl-3-diphenylphosphinoylbutyl benzyl ether **36j** (252 mg, 0.49 mmol, 65:35 mixture of **36j** and **35j**) and sodium hydride (29 mg of a 60% dipersion in oil, 0.74 mmol) gave a crude product, which was purifed by flash chromatography eluting with 30:1 hexane–Et_2O to give the *alkene* (*Z*)-**49c** (91 mg, 60%, *Z*:*E* >95:5 mixture) as a liquid, R_f 0.85 (1:1 EtOAc–hexane); $[\alpha]_D^{20}$ −12.7 (*c* 0.75 in $CHCl_3$; 100% ee) (Found: MNa$^+$, 337.1566. $C_{22}H_{28}O_2$ requires *MNa*, 337.1568); ν_{max}/cm^{-1} ($CHCl_3$) 1630 (C=C) and 1596 (Ph); δ_H (400 MHz; $CDCl_3$) 7.5–7.2 (15 H, Ph × 3), 6.45 (1 H, d, *J* 11.7, PC*H*), 5.81 (1 H, td, *J* 7.1 and 11.7, C*H*=CHPh), 4.55 (1 H, d, *J* 11.8, PhCH_AH$_B$), 4.47 (1 H, dd, *J* 5.7 and 7.7, PhC*H*OBn), 4.33 (1 H, d, *J* 11.9, PhCH$_A H_B$), 2.99 (1 H, m) and 2.81 (1 H, m); δ_C (100 MHz; $CDCl_3$) 141.9$^-$, 138.9$^-$, 137.4$^-$ (*ipso*-Ph × 3), 132.9$^+$, 132–126 (m, remaining Ph × 3), 81.2$^+$ (*C*HOBn), 70.5$^-$ (Ph*C*H$_2$) and 37.4$^-$; *m*/*z* (FAB) 337.2 (100, MNa$^+$).

(1*E*,4*R*)-1-(4-Methoxyphenyl)oct-1-en-4-yl benzyl ether 49b

By the same general method, (1*S*,2*S*,4*R*)-4-benzyloxy-2-diphenylphosphinoyl-1-(4-methoxyphenyl)octan-1-ol **37d** (268 mg, 0.49 mmol, 72:18 mixture of **37d** and **38b**) and sodium hydride (29 mg of a 60% dispersion in oil, 0.74 mmol) gave a crude product which was purified by flash chromatography eluting with 30:1 hexane–EtOAc to give the *alkene* (*E*)-**49b** (99 mg, 62%) as a liquid, R_f 0.27 (20:1 hexane–EtOAc); $[\alpha]_D^{20}$ −1.7 (*c* 1.13 in $CHCl_3$) (Found: M$^+$, 324.2089. $C_{22}H_{28}O_2$ requires *M*, 324.2089); ν_{max}/cm^{-1} ($CHCl_3$) 1609 (C=C); δ_H (400 MHz; $CDCl_3$) 7.4–7.25 (7 H, m, Ph and remaining Ar), 6.87 (2 H, d, *J* 8.7, Ar), 6.43 (1 H, br d, *J* 15.8, C*H*=CHCH$_2$), 6.13 (1 H, td, *J* 7.2 and 15.8, CH=C*H*CH$_2$), 4.62 (1 H, d, *J* 11.7, PhCH_AH$_B$), 4.56 (1 H, d, *J* 11.7, PhCH$_A H_B$), 3.83 (3 H, s, OMe), 3.52 (1 H, quin, *J* 5.8, C*H*OBn), 2.48 (2 H, br t, *J* 5.9, CH=CHCH_2), 1.7–1.3 (6 H, m) and 0.93 (3 H, t, *J* 7.3, Me); δ_C (100 MHz; $CDCl_3$) 158.8$^-$ (*ipso*-Ar), 139.0$^-$ (*ipso*-Ph), 131.3$^+$, 130.6$^-$, 128.3$^+$, 127.8$^+$, 127.4$^+$, 127.3$^+$, 124.8$^+$, 113.9$^+$ (Ar), 79.1$^+$ (*C*HOBn), 74.5$^-$ (Ph*C*H$_2$), 55.3$^+$ (OMe), 37.7$^-$, 33.8$^-$, 27.7$^-$, 22.9$^-$ and 14.1$^+$ (Me); *m*/*z* 324.2 (40%, M$^+$), 147.1 (85, ArCH=CHCH$_2$) and 91.1 (100, Bn).

(1*E*,4*R*)-1-Phenyloct-1-en-4-yl benzyl ether 49d

By the same general method, (1*S*,2*S*,4*R*)-4-benzyloxy-2-diphenylphosphinoyl-1-phenyloctan-1-ol **37i** (200 mg, 0.39 mmol, 70:30 mixture of **37i** and **38i**) and sodium hydride (23 mg of a 60% dispersion in oil, 0.58 mmol) gave a crude product which was purified by flash chromatography eluting with 30:1

hexane–EtOAc to give the *alkene* (*E*)-**49d** (22 mg, 19%) as a liquid, R_f 0.81 (1:1 EtOAc–hexane); $[\alpha]_D^{20}$ −9.8 (*c* 0.04 in $CHCl_3$) (Found: M^+, 294.1998. $C_{21}H_{26}O$ requires *M*, 294.1984); ν_{max}/cm^{-1} ($CHCl_3$) 1601 (C=C); δ_H (400 MHz; $CDCl_3$) 7.4–7.15 (5 H, m, Ph), 6.46 (1 H, br d, *J* 15.8, C*H*=CHCH$_2$), 6.26 (1 H, td, *J* 7.2 and 15.6, CH=C*H*CH$_2$), 4.61 (1 H, d, *J* 11.7, PhCH_AH_B), 4.54 (1 H, d, *J* 11.7, PhCH$_A$$H_B$), 3.51 (1 H, quin, *J* 5.8, C*H*OBn), 2.49 (2 H, br t, *J* 6.0, CH=CHCH_2), 1.7–1.2 (6 H, m) and 0.91 (3 H, t, *J* 7.3, Me); δ_C (100 MHz; $CDCl_3$) 138.9$^-$, 137.7$^-$ (*ipso*-Ph × 2), 131.9$^+$, 128.4$^+$, 128.3$^+$, 127.8$^+$, 127.4$^+$, 127.0$^+$, 126.9$^+$, 126.0$^+$, 78.9$^+$ (*C*HOBn), 71.1$^-$ (Ph*C*H$_2$), 37.6$^-$, 33.7$^-$, 27.6$^-$, 22.8$^-$ and 14.1$^+$ (Me); *m*/*z* 324.2 (30%, M^+) and 91.1 (100, Bn).

(1*S*,3*E*)-1,4-Diphenylbut-3-en-1-yl benzyl ether 49c

By the same general method, (1*S*,3*S*,4*S*)-1,4-diphenyl-3-diphenylphosphinoylbutyl benzyl ether **37j** (207 mg, 0.40 mmol, 72:28 mixture of **37j** and **38j**) and sodium hydride (24 mg of a 60% dipersion in oil, 0.60 mmol) gave a crude product, which was purifed by flash chromatography eluting with 30:1 hexane–Et_2O to give the *alkene* (*E*)-**49c** (91 mg, 60%, *E*:*Z* >95:5 mixture) as a liquid, R_f 0.33 (30:1 hexane–EtOAc); $[\alpha]_D^{20}$ −23.2 (*c* 2.40 in $CHCl_3$; 100% ee) (Found: MNa^+, 337.1566. $C_{22}H_{28}O_2$ requires *MNa*, 337.1566); ν_{max}/cm^{-1} ($CHCl_3$) 1630 (C=C) and 1596 (Ph); δ_H (400 MHz; $CDCl_3$) 7.45–7.2 (15 H, Ph × 3), 6.44 (1 H, d, *J* 15.8, PC*H*), 6.24 (1 H, td, *J* 7.2 and 15.8, C*H*=CHPh), 4.53 (1 H, d, *J* 11.9, PhCH_AH_B), 4.44 (1 H, dd, *J* 5.6 and 7.8, PhC*H*OBn), 4.30 (1 H, d, *J* 11.9, PhCH$_A$$H_B$), 2.78 (1 H, m) and 2.62 (1 H, m); δ_C (100 MHz; $CDCl_3$) 141.9$^-$, 138.5$^-$, 137.7$^-$ (*ipso*-Ph × 3), 132.1$^+$, 128–126 (m, remaining Ph × 3), 81.4$^+$ (*C*HOBn), 70.5$^-$ (Ph*C*H$_2$) and 41.9$^-$; *m*/*z* (FAB) 337.2 (100, MNa^+).

(1*S*,3*E*)- and (1*S*,3*Z*)-1,4-Diphenyl-3-methylbut-3-en-1-yl benzyl ether 53

n-Butyllithium (2.3 cm^3 of a 1.3 mol dm^{-3} solution in hexanes, 3.0 mmol) was added dropwise to the phosphine oxide **51** (1.16g, 2.72 mmol) in dry THF (10 cm^3) at −78 °C. After 15 min, freshly distilled furfural (0.25 cm^3, 3.0 mmol) was added dropwise, the reaction was stirred for 30 min at −78 °C, warmed gradually to room temperature over 1 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. By the general method described above, a portion of this crude product (239 mg, *ca.* 0.46 mmol) and sodium hydride (28 mg, 0.70 mmol) gave the *alkenes* **53** (58 mg, 35% over 2 steps, *E*:*Z* 64:36 mixture) as a liquid, R_f 0.38 (30:1 hexane–EtOAc); $[\alpha]_D^{20}$ −19.2 (*c* 2.20 in $CHCl_3$; 100% ee) (Found: PhCHOBn, 197.0975. $C_{23}H_{24}O$ requires *PhCHOBn*, 197.0966); ν_{max}/cm^{-1} ($CHCl_3$) 1630 (C=C) and 1596 (Ph); δ_H (400 MHz; $CDCl_3$) 7.45–7.25 (15 H, Ph × 3), 6.40 (1 H, dd, *J* 1.9 and 3.3, PCH^{maj}), 6.35 (1 H, dd, *J* 1.8 and 3.3, PCH^{min}), 4.61 (1 H, dd, *J* 5.9 and 8.0, C*H*OBn^{min}), 4.50 (1 H, m, C*H*OBn^{maj} and PhC$H_AH_B^{maj+min}$), 4.29 (1 H, d, *J* 12.0, PhCH$_A$$H_B^{min}$), 4.28 (1 H, d, *J* 12.0, PhCH$_A$$H_B^{maj}$), 3.02 (1 H, dd, *J* 8.0 and 13.2, C$H_AH_B^{min}$), 2.72 (1 H, $m^{maj+min}$), 2.46 (1 H, dd, *J* 5.0 and 13.8, CH$_A$$H_B^{maj}$), 1.93 (3 H, d, *J* 0.9, Me^{maj}) and 1.76 (3 H, d, *J* 1.0, Me^{min}); δ_C (100 MHz; $CDCl_3$) 153.6$^-$ (*C*Me=CH^{maj}), 153.2$^-$ (*C*Me=CH^{min}), 142.5$^-$ (min), 142.2$^-$ (maj), 138.4$^-$ (maj), 135.9$^-$ (min), 134.7$^-$ (maj, *ipso*-Ph), 128.5–126.5 (m, remaining Ph × 3), 116.6$^+$ (maj), 116.1$^+$ (min), 81.8$^+$ (*C*HOBn^{min}), 80.3$^+$ (*C*HOBn^{maj}), 70.4$^-$ (Ph*C*H$_2^{maj+min}$), 31.9$^-$ (CH$_2^{maj+min}$), 26.1$^+$ (Me^{min}) and 19.2$^+$ (Me^{maj}); *m*/*z* 197.1 (85%, PhCHOBn) and 91.1 (100, Bn).

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