Horner-Wittig Reactions of β-Aminoalkyl- and β-*N*-Acylaminoalkyldiphenylphosphine Oxides: Synthesis of *N*-Allyl Amines and Amides and 5-Diphenylphosphinoyl-2-phenyl-5,6-dihydro-4*H*-1,3-oxazines

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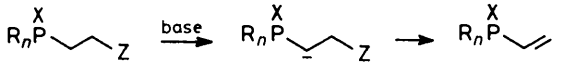
Lithium derivatives of β-diphenylphosphinoyl-alkyl amines and dilithium derivatives of the corresponding amides combine with aldehydes or ketones in the Horner-Wittig reaction. Separation of the diastereoisomeric intermediates leads to single positional and geometrical isomers of *N*-allyl amines and amides. Attempted rearrangement of the same intermediates in acid solution gives dihydro-oxazines or, in one case, a γ-*N*-acylaminoallyl diphenylphosphine oxide.

Amino substituted ylides have been used in the synthesis of allylic amines.[1-5] This method has been preferred to the attack of amines on allylic electrophiles to avoid uncertainty in the position of the new C–N bond on the allylic framework.[6-9] Yields in these Wittig reactions are moderate and control over the geometry of the double bond is only partly achieved by choice of conditions.[1,2] We report[10] that the corresponding phosphine oxides can be used to make single isomers (*E* or *Z*) of allylic amines *via* purification of the intermediates, *e.g.* (**16**).

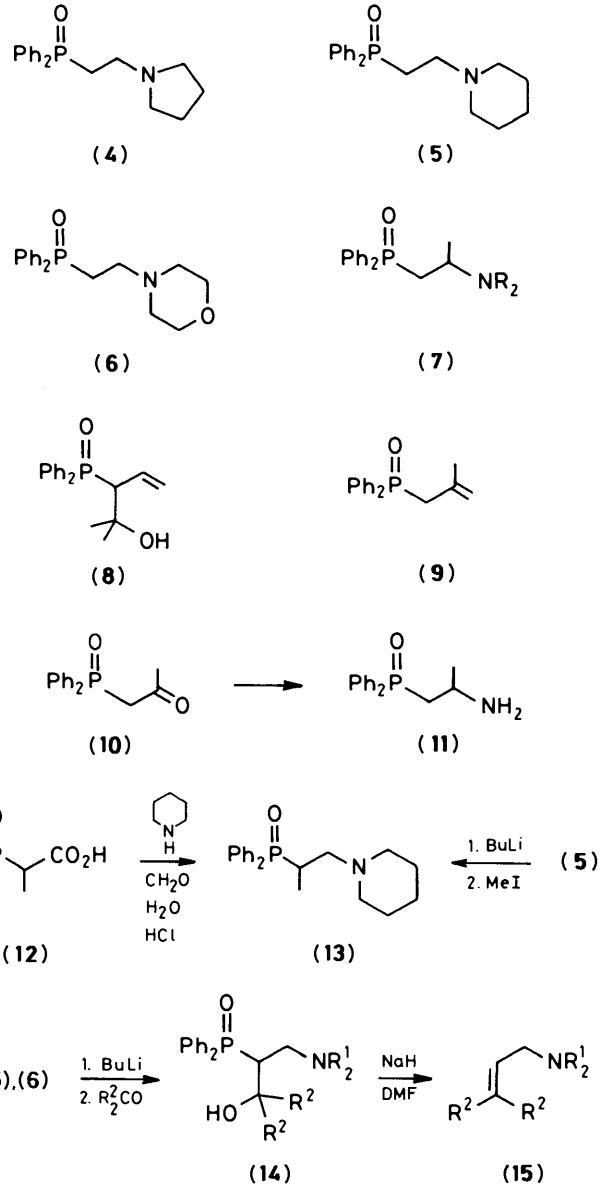


Our previous work has established the value of the Horner-Wittig reaction with the diphenylphosphinoyl (Ph_2PO) group as a regio- and stereo-chemically controlled route to unsaturated esters,[11] alcohols,[12] and ketones[13] using phosphine oxides with functional groups on the α or γ atom of the alkyl chain. Little work has been reported with functional groups in the β position (**1**) as anions (**2**) from such compounds tend to fragment. Fragmentation is enhanced by poor anion stabilisation and by a good leaving group Z. Amide anions (R_2N^-) are very poor leaving groups and the anions from β-aminoalkyl phosphine oxides (**4**)—(**6**) can be used in Horner-Wittig reactions at 0 to −78 °C even though some analogous phosphonates[14] fragment under more vigorous conditions.

The β-aminoalkyl phosphine oxides were prepared by straightforward methods. The addition of amines to vinyl or allylic (*via* vinylic) diphenylphosphine oxides succeeds[15] for compounds with no substituents on carbon, (**4**)—(**6**), or one on C-2 (**7**) but fails with one substituent on C-1, *e.g.* (**8**) or two on C-2, *e.g.* (**9**). The primary amine (**11**) was made by reductive amination of the ketone (**10**).[16] A decarboxylation Mannich reaction[17] on the acid (**12**) gave (**13**), but methylation of (**5**) gave a higher yield.

Treatment of the simple amines (**4**)—(**6**) with butyl-lithium (BuLi) at 0 °C in tetrahydrofuran (THF) gave yellow solutions of the lithium derivatives which were efficiently captured by symmetrical ketones at −78 °C to give the crystalline alcohols (**14**) in good yield (Table 1). Elimination[18] (NaH, DMF, 30 °C) gave allylic amines (**15**) in high yield, isolated as their hydrochlorides. Elimination with 1,5-diazabicyclo[4.3.0]non-5-ene[19] (DBN) was also successful but offered no advantages.

Reactions of unfunctionalised phosphine oxides with aldehydes are normally *erythro* selective.[19] This selectivity is affected by functional groups on the alkyl chain of the phosphine oxide:[12] an acetal in the γ or δ position reduces



selectivity[13] and it disappears with an α-MeO group.[11] The β-aminoalkylphosphine oxides (**4**)—(**6**) similarly show no selectivity in reactions with aldehydes (Table 2). However, separation of the diastereoisomers of the adducts (**16**) and

Table 1. Synthesis of allylic amines (**15**)

Starting material	Ketone	Adduct	Yield (**14**) (%)	Yield Amine·HCl (**15**) (%)
(**4**)	Me_2CO	(**14a**)	70	76
(**5**)	Me_2CO	(**14b**)	75	72
(**6**)	Me_2CO	(**14c**)	65	90
(**4**)	$(CH_2)_5CO$	(**14d**)	70	85 (80)[a]
(**5**)	$(CH_2)_5CO$	(**14e**)	77	83 (70)[a]
(**6**)	$(CH_2)_5CO$	(**14f**)	68	81

[a] Yield with DBN as base.

Table 2. Adducts of β-aminoallylphosphine oxides and aldehydes

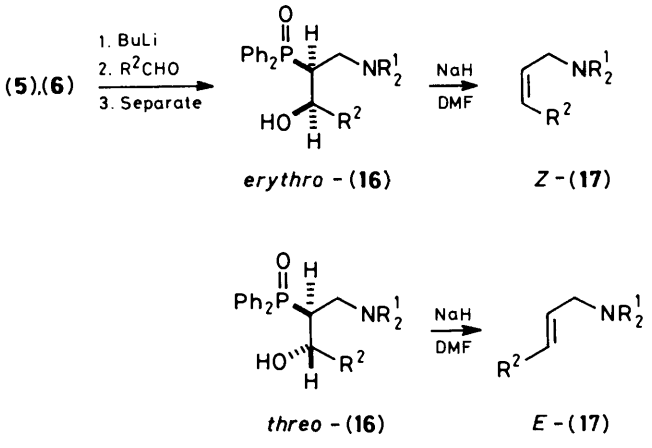
Starting Material	R^2	Adduct	Yield %	Separation[a] method	Ratio *erythro*:*threo*	Product yield: *erythro* (**9**) (%)	Product yield: *Z*-(**17**) (%)	Product yield: *threo* (**9**) (%)	Product yield: *E*-(**17**) (%)
(**5**)	Me	(**9a**)	69	A,B	49:51	34	81	35	74
(**5**)	Ph	(**9b**)	80	B	48:52	*b*	86	*b*	82
(**6**)	Me	(**9c**)	75	B	50:50	38	84	38	86
(**6**)	Ph	(**9d**)	77	C	66:34	57[c]	61[d]	29[c]	68[d]
(**4**)	Me	(**9e**)	79	—	50:50	—	—	—	—

[a] Separation methods: A, h.p.l.c.; B, fractional crystallisation; C, (i) Bu^tMe_2SiCl, imidazole, DMF; and (ii) p.l.c. eluting with ether. [b] Portion separated only. [c] Yield of silyl ethers. [d] Yield for desilylation and elimination.

Table 3. Assignment of configuration to allylic amines (**17**)

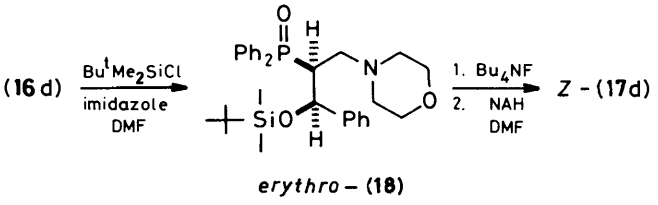
Compound	*Z*-isomers: CH=CH[a]	*Z*-isomers: J_{HH}/Hz	*E*-isomers: CH=CH[a]	*E*-isomers: J_{HH}/Hz
(**10a**)	715	11	965	15
(**10b**)	*b*	11	960	16
(**10c**)	720	11	960	16.5
(**10d**)	670	12	980	16

[a] Out-of-plane deformation in the i.r. spectrum (cm^{-1}). [b] Obscured by aromatic out-of-plane deformations.



stereospecific elimination of $Ph_2PO_2^-$ give single geometrical isomers of the allylic amines (**17**).

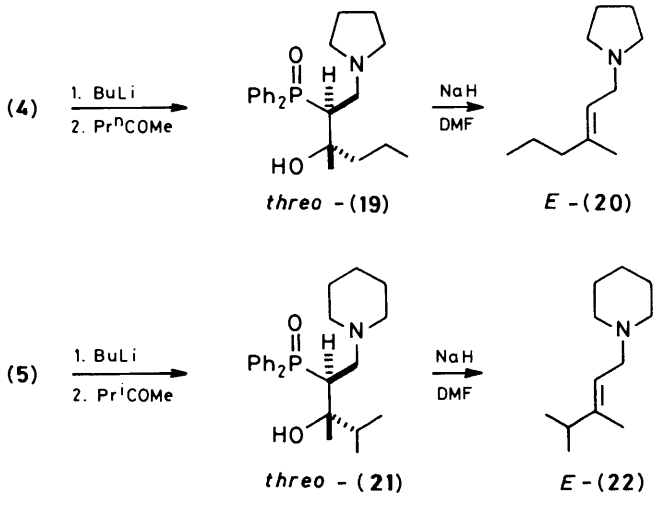
Though the diastereoisomers of one adduct (**16a**) could be separated by h.p.l.c., a more general method was fractional crystallisation giving good recovery of pure *erythro* and *threo* adducts (**16a**—**c**). The silyl ethers (**18**) could be separated by preparative layer chromatography (p.l.c.) which gave an even better recovery of both isomers. However, the silyl ethers of the other aldehyde adducts could not be separated on silica.



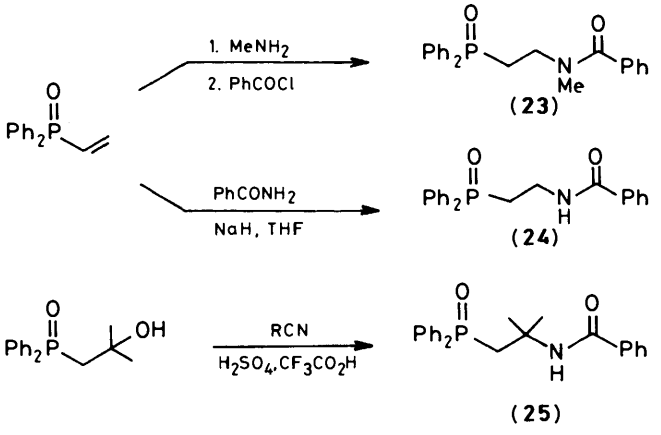
Each pure diastereoisomer (**16**) eliminated $Ph_2PO_2^-$ on treatment with NaH in DMF [after desilylation for (**16 d**)] to give single geometrical isomers or allylic amines (**17**) (Table 2), the configuration of whose double bonds was assigned by i.r. and n.m.r. spectra (Table 3). The *erythro* or *threo* configuration of alcohols (**16**) or silyl ethers (**18**) was assigned from these results as the elimination is stereospecifically *syn*.[20]

Two ketone adducts (**19**) and (**21**) were also prepared. Stereoselectivity in the Horner–Wittig synthesis of tri-substituted double bonds[21] is usually less than that observed in the synthesis of di-substituted double bonds. The amino-substituted adducts (**19**) and (**21**) were, however, formed with higher stereoselectivity than the aldehyde adducts (**16**) but with the *threo* adducts predominating by 72:28 for (**19**) and 80:20 for (**21**). These diastereoisomers could be separated by flash chromatography.[22] All four allylic amines *E* and *Z* (**20**) and (**22**) were formed stereospecifically and in high yield upon base-catalysed elimination and were isolated as their hydrochlorides. The free bases *E* and *Z*-(**22**) could be isolated in rather lower yield by pyrolytic elimination (170 °C/0.2 mmHg) from (**21**). These stereochemical assignments are based on the geometry of the allylic amines (**20**) and (**22**) which were assigned by nuclear Overhauser experiments.

Attempts to extend the allylamine syntheses revealed that even one additional alkyl substituent on the phosphine oxide, *e.g.* (**7**), severely hindered nucleophilic reactions of the corresponding lithium derivatives. Reactions with acetone returned starting materials: [$^2H_6$]acetone gave deuteriated starting materials. The primary amine (**11**) is obviously less hindered but no adducts could be formed from it.



Synthesis of N-*Allylamides.*—We therefore turned to the dianions from phosphine oxides having a β-amido group (**23**)—(**25**) in the hope that they would be less hindered and more reactive than the monoanions from the amines (**18**). These amides were prepared by acylation of the amines [the isolation of the amine is not necessary, *e.g.* in the synthesis of (**23**)], by the addition of the anion of acetamide to diphenylvinylphosphine oxide to give (**24**), or by the Ritter reaction[23] to give (**25**).



Treatment of either amide (**26**) or (**25**) with one equivalent of BuLi gave a colourless solution, presumably of the anion formed by removal of the amide proton. A second equivalent of BuLi gave a deep orange-red solution of the dilithium derivative. The second proton to be removed must have been one from the carbon atom next to phosphorus as the 'dianions' reacted with aldehyde or ketones to give adducts in good yield providing rigorously dry conditions were used. The permanent colour of the 'dianion' should appear immediately after more than one equivalent of BuLi is added: if much more is needed, yields will be low. The dianion is also necessary to prevent β-elimination. Treatment of the *N*-methyl derivative (**23**) with one equivalent of LDA [lithium di(isopropyl)amide] and attempted capture of the resulting anion with MeI gave instead a 76% yield of *N*-methylbenzamide.

The monomethylated phosphine oxide (**26**) already has a chiral centre so even its adducts (**27**) with symmetrical ketones could have been formed as mixtures of diastereoisomers. However, they appeared (n.m.r., m.p., t.l.c.) to be single compounds, though this is irrelevant in the synthesis of the allyl amide (**28**) and the stereochemistry shown is given by comparison with the aldehyde adducts below. Elimination under the usual conditions gave good yields of the *N*-allylamides (**28**).

Addition of acetaldehyde to the dilithium derivative of (**26**) gave only two diastereoisomers of the adduct (**29**), separated by h.p.l.c. (Table 4). Each gave on elimination a single and different

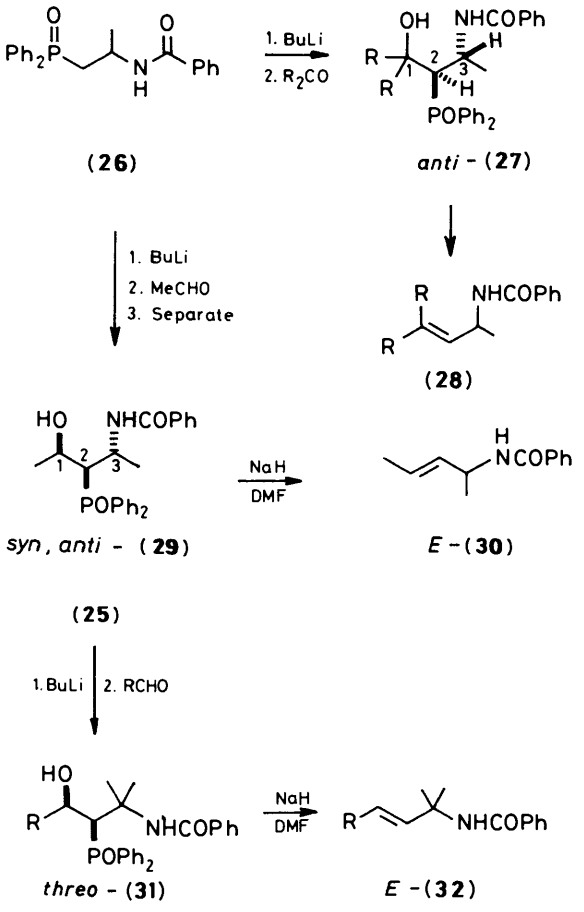


Table 4. Stereocontrolled synthesis of *N*-allylamides

Starting material	Aldehyde	Product	Yield (%)	*erythro*:*threo*	Yield of products (%) *erythro* (29)/(31)	*Z* (30)/(32)	*threo* (29)/(31)	*E* (30)/(32)
(22)	MeCHO	(27)	68	55:45	37.5	82	30.5	76
(23)	MeCHO	(29a)	72	30:70	*a*	82	*a*	82
(23)	PrⁱCHO	(29b)	60	22:78	13	84	47	84
(23)	PhCHO	(29c)	80	5:95	4	—	80	84

[a] Diastereoisomers were not separated: product (32) is an *E*,*Z* mixture.

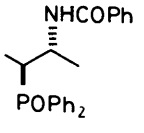
Table 5. Stereochemistry of the allylamides (**30**) and (**32**)

		Z-isomer		*E*-isomer	
Compound	R	CH=CH[a]	J_{HH}/Hz	CH=CH[a]	J_{HH}/Hz
(**30**)	Me	*b*	11[c]	965	16[c]
(**30b**)	Pr^i	*b*	12	960	15
(**30c**)	Ph	—	—	940	16[d]

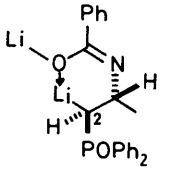
[a] Out-of-plane deformation (cm^{-1}). [b] Obscured by aromatic out-of-plane deformations. [c] Determined by decoupling (see text). [d] Determined by a praeseodymium shift reagent experiment.

isomer of the *N*-allylamide (**30**). Irradiation of the vinylic methyl group in the n.m.r. spectrum of these isomers allowed the determination of the olefinic coupling constants and hence the geometry of the double bond and the relative stereochemistry of two of the chiral centres in (**29**) (Table 5).

The two diastereoisomers of (**29**) must therefore have the *same* (*anti*) relative stereochemistry at the third chiral centre (C-3). An *X*-ray crystal structure determination on the isomer of (**29**) which gave *E*-(**30**) on elimination revealed that it was *syn*, *anti*-(**29**), that is (*RS,RS,RS*). The *erythro*:*threo* selectivity in this series is again poor but the selectivity at the third chiral centre is almost complete. This is a property of the dianion of (**26**) and the aldehyde is not involved: methylation of the dianion gave a 78% yield of a single diastereoisomer (presumably *anti*) of (**33**). One simple explanation would be that the electrophile attacks a chelated structure such as (**34**) with retention at C-2.



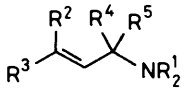
anti-(**33**)



(**34**)

By contrast, reactions of the dilithium derivative of the dimethylated phosphine oxide (**25**) are stereoselective at the two chiral centres which determine the geometry of the double bond in the final product, that is the *threo*-adduct (**31**) is favoured (Table 4). Selectivity increases with the size of R in RCHO and is almost complete for PhCHO. The stereochemistry of these adducts was assigned after stereospecific elimination to give the allyl amides (**32**) (Table 5).

These routes make available allylic amines (**35**) of a variety of substitution patterns. Compounds with one or two alkyl groups on the double bond (C-3) (**15**), (**17**), (**20**), and (**22**) may be synthesised directly from the β-aminoalkylphosphine oxides (**4**)—(**6**). Compounds with an additional one (**28**) and (**30**) or two (**32**) alkyl groups at C-2 must be approached *via* the amides. Compounds with four substituents (**35**; R^{2-5} = alkyl, aryl) cannot be made by these routes. In each group of allyl amines, control over the geometry of the double bond is possible for most compounds, though the synthesis of compounds *Z*-(**32**) can be achieved in only low material conversion.



(**35**)

Table 6. Atom co-ordinates (10^4)

	x/*a*	*y*/*b*	*z*/*c*
C(1)	5 405(3)	−1 860(4)	−670(5)
C(2)	5 444(3)	−1 021(4)	−1 569(4)
O(2)	4 817(2)	−141(3)	−1 558(3)
C(3)	6 432(3)	−546(3)	−1 519(3)
C(4)	6 416(3)	348(4)	−2 380(3)
C(5)	5 875(4)	18(5)	−3 535(4)
P(6)	7 038(1)	−82(1)	−155(1)
O(7)	6 462(2)	577(3)	427(3)
C(8)	7 496(3)	−1 278(4)	636(4)
C(9)	7 827(3)	−2 194(4)	212(5)
C(10)	8 148(4)	−3 096(5)	886(6)
C(11)	8 139(4)	−3 041(6)	1 981(7)
C(12)	7 834(5)	−2 129(7)	2 402(6)
C(13)	7 490(4)	−1 229(5)	1 743(4)
C(14)	8 042(3)	679(4)	−307(4)
C(15)	8 148(5)	1 718(5)	143(5)
C(16)	8 935(7)	2 330(7)	62(6)
C(17)	9 549(6)	1 936(10)	−489(9)
C(18)	9 446(5)	931(8)	−908(8)
C(19)	8 685(4)	276(5)	−842(5)
N(20)	6 041(3)	1 360(3)	−2 058(3)
C(21)	6 367(3)	2 348(4)	−2 234(4)
O(22)	7 026(2)	2 480(3)	−2 651(3)
C(23)	5 862(4)	3 289(4)	−1 883(4)
C(24)	4 907(4)	3 291(4)	−1 981(5)
C(25)	4 464(5)	4 206(5)	−1 714(7)
C(26)	4 985(6)	5 104(6)	−1 335(9)
C(27)	5 957(6)	5 106(6)	−1 166(9)
C(28)	6 390(5)	4 201(5)	−1 472(6)

X-*Ray Crystal Structure Determination of* (2RS,3RS,4RS)-4-*Benzamido-3-diphenylphosphinoylpentan-2-ol syn, anti*-(**29**).—*Crystal data.* $C_{24}H_{26}NO_3P$, M = 407.5 space group $P2_1/n$ a = 14.771(2), b = 12.273(2), c = 12.625(2) Å, β = 103.98(1)°, U = 2 220.9 Å^3, Z = 4, D_c = 1.22 g cm^{-1}, λ(Cu-K_α) = 1.5418 Å, μ(Cu-K_α) = 11.93 cm^{-1}.

Data collection. Intensity measurements were obtained from a Syntex $P2_1$ diffractometer at 18 °C using graphite monochromatised Cu-K_α radiation. Integrated relative intensities were collected for 4 389 independent reflections with $3 < 2\theta < 30°$ by the $\theta/2\theta$ scan method. After correcting for Lorentz and polarisation effects, scaling and merging, 2 737 of a total of 3 795 unique reflections had $F > 3\sigma$ and were treated as observed.

Structure Solution and Refinement.—The crystal structure was solved by direct methods using the EEES option of the SHELX-76 suite of programs. The positions of hydrogen atoms bonded to carbon were calculated and included in the model with H riding on C and a C–H distance of 0.99 Å. Methyl groups were refined as rigid bodies pivoting on C. The full-matrix least-squares refinement using a unitary weighting scheme and anisotropic thermal parameters for the non-hydrogen atoms was terminated at R = 0.060. Atomic co-ordinates for non-hydrogen atoms are given in Table 6 whilst those for hydrogen atoms, the thermal parameters, bond distances, and bond angles relating to this stage of the refinement are available from the Cambridge Crystallographic Data Centre.* Further refinement of the structure was considered unmeaningful as two of the three phenyl rings were suffering from large anisotropic thermal vibration.

* See 'Instructions for Authors' (1987), *J. Chem. Soc., Perkin Trans. 1*, 1987, Issue 1.

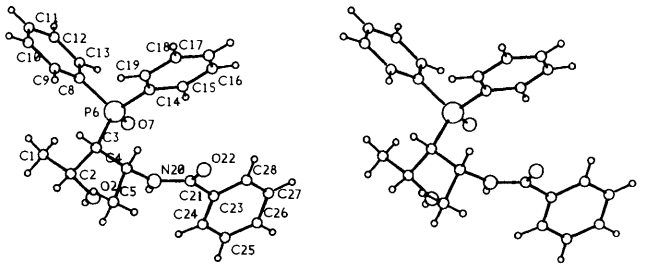
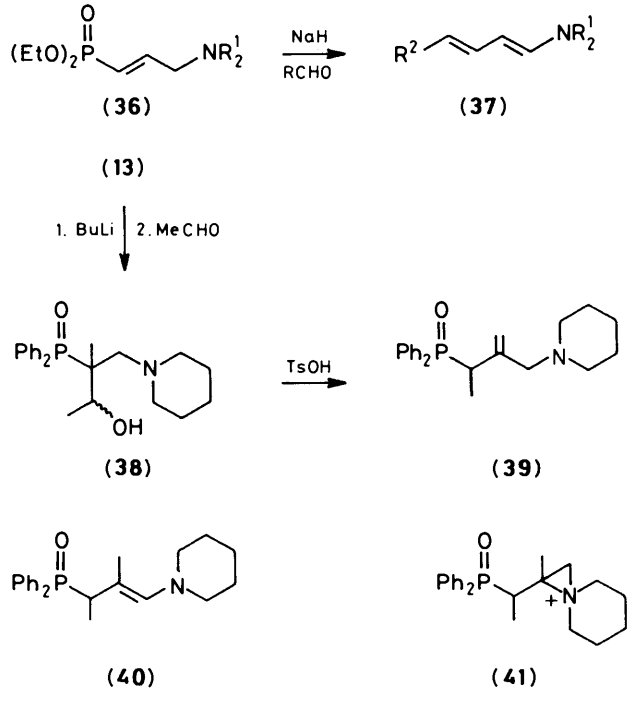


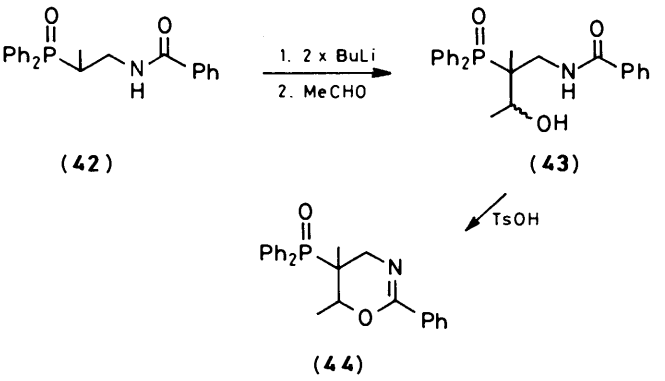
Figure. Molecular structure of the *syn*, *anti*-adduct (**29**)

Reaction of the Horner–Wittig Intermediates with Acid.— Rearrangement of the Horner–Wittig intermediates by diphenylphosphinoyl migration,[24] might lead to phosphine oxides analogous to the phosphonate (**36**) used by Lavielle and Sturtz[25] to make amino dienes (**37**). The adduct (**38**) rearranged to the alkene (**39**) in poor yield. This unusual[24] preference for the less substituted double bond [rather than (**40**)] may be because the nitrogen is protonated or because it participates (**41**). Attempts to convert (**39**) into the enamine (**40**) failed.

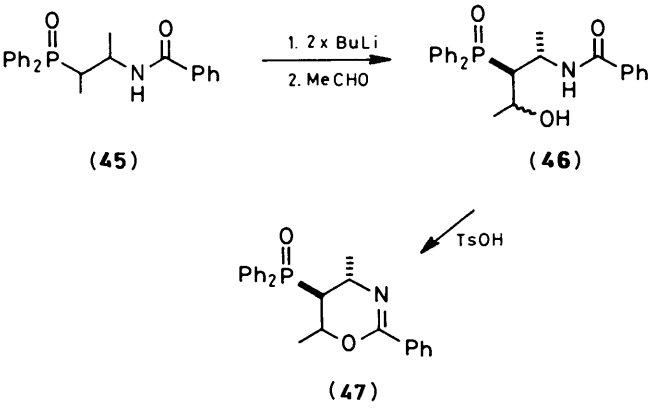


Further work was carried out on amides rather than amines as their adducts with aldehydes are easier to prepare and the nitrogen atom should remain unprotonated during the rearrangement. The dianion of the amide (**42**) gave the acetaldehyde adduct (**43**) in reasonable yield. Treatment of this alcohol under the usual rearrangement conditions gave a new product, the dihydro-oxazine (**44**), as a single diastereoisomer. Evidently the amide participates in the solvolysis of the alcohol more rapidly than the Ph_2PO group migrates. We have previously observed[24] that methyl migration from an alternative migration origin also successfully competes with Ph_2PO migration.

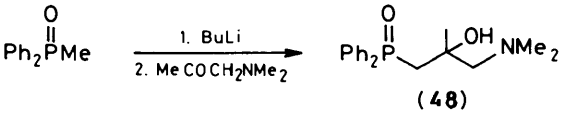
A single diastereoisomer of an oxazine (**47**) was also formed in the series with an extra methyl group. The stereochemistry of two of the chiral centres in the intermediate (**46**) is known from the *X*-ray crystal structure but that of the third is unknown. In



each cyclisation, (**43**) to (**44**) and (**46**) to (**47**), a mixture of diastereoisomers gave a single diastereoisomer of an oxazine. Epimerisation must occur at the hydroxy carbon atom during the cyclisation.

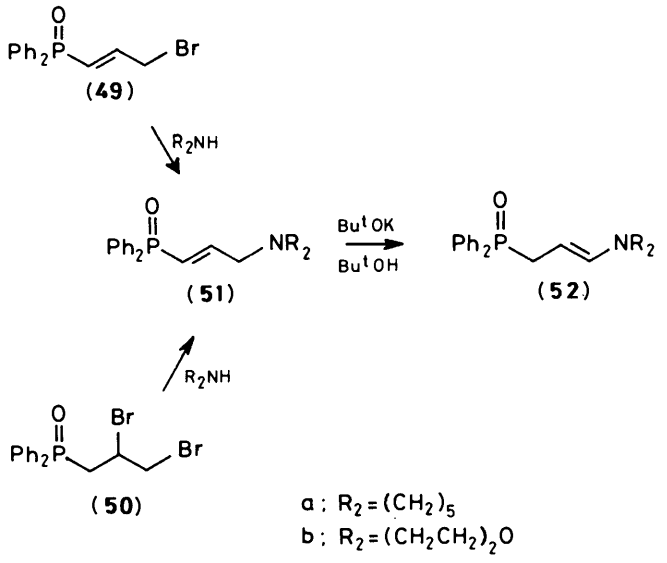


An alternative route to an allylic phosphine oxide would be dehydration (without rearrangement[24]) of the tertiary alcohols, *e.g.* (**48**), derived from a primary alkyl phosphine oxide and an α-amino ketone. The adduct (**48**) was easily prepared but did not dehydrate under the normal conditions [TsOH, benzene, reflux or hot trifluoroacetic acid (TFA)]. Other conditions [TsCl, methanesulphonyl chloride, or $SOCl_2$ with Et_3N or 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU)] gave mixtures of products with no vinyl protons in the n.m.r.



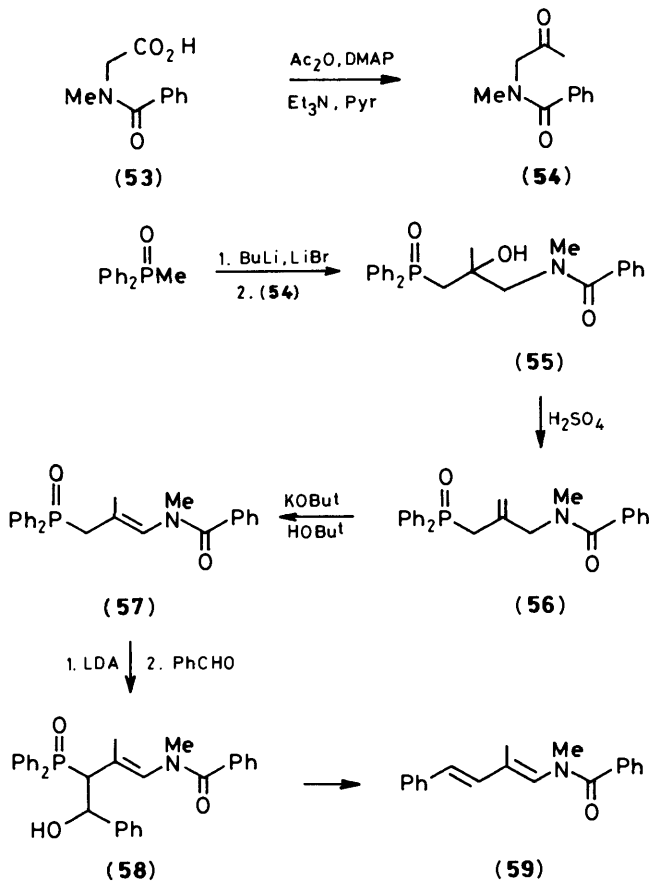
The γ-dialkylamino allyl phosphine oxides (**51**) could be prepared by displacement from the allylic bromide[26] (**49**) or from the dibromide[26] (**50**) in one step with piperidine or morpholine. Equilibration in base gave the enamines (**52**) demonstrating the higher double-bond attraction[27] of R_2N over Ph_2PO. The equilibration of (**51**) and (**52**) in base shows that an allylic anion stabilised by Ph_2PO can be formed from (**22**), but attempts to use these anions (BuLi or LDA) in reactions with alkyl halides (MeI) or carbonyl compounds (Me_2CO) failed.

The Dakin–West reaction[28] provides a general route to α-*N*-acylamino ketones *via* azlactones. We found that *N*-benzoylsarcosine (**53**) required vigorous conditions [heating under reflux in pyridine with Ac_2O and a catalytic amount of 4-*N*,*N*-



dimethylaminopyridine (DMAP)], but gave a good yield of the amido ketone (**54**). This in turn, gave the tertiary alcohol (**55**) in good yield, using THF saturated with LiBr for the anion reaction to reduce enolisation of the ketone.

Attempted dehydration of the tertiary alcohol (**55**) in TsOH or TFA returned starting material after the addition of water. Treatment with concentrated sulphuric acid finally gave dehydration and produced the *exo*-methylene compound (**56**). Equilibration of the *exo*-methylene product (**56**) to the more stable *N*-acyl enamine (**57**) occurred in basic solution ($KOBu^t$, $HOBu^t$), giving (**57**) in 72% yield from the alcohol (**55**). This



reagent (**57**) is analogous to the phosphonate (**36**) but has a substituted allylic portion, is an amide and not an amine, and of course a phosphine oxide and not a phosphonate ester.

Anion formation (LDA) and reaction with PhCHO gave the *N*-acyl dienamine (**59**) with only a little intermediate (**58**). The intermediate alcohols, are normally isolated in these Horner–Wittig reactions but γ-phenylthio allylic phosphine oxide anions also give[26] dienes in one step, presumably because the elimination of $Ph_2PO_2^-$ is accelerated by the allylic conjugation in the transition state.[29] The new double bond is *E* as is usually the case with one-step Horner-Wittig reactions.[29] 1-*N*-Acylaminobutadienes have been made by Overman[30] and used in Diels–Alder reactions.

Experimental

^1H N.m.r. spectra were recorded on Bruker WH-250, Varian Associates EM 390, 360A, or CFT-20 instruments. Tetramethylsilane was used as the internal standard with chemical shifts (δ) given in p.p.m. I.r. spectra were recorded on Perkin-Elmer 257 or 297 grating spectrometers. Mass spectra were recorded on A.E.I.-Kratos MS20, MS902 or VG 7070F spectrometers. High resolution spectra were recorded using a DS 50S data system. Ionisation was affected by electron impact, except where otherwise stated. CI refers to chemical ionisation using ammonia. T.l.c. was performed on silica GF_{254} (0.25 mm) plates, p.l.c. on silica GF_{254} (1 mm) plates and visualised by u.v. Column chromatography was performed on Merck Silica Kieselgel 60, 60—230 mesh (230—400 mesh for flash chromatography). H.p.l.c. was carried out using a 50 cm × 1 cm steel column packed with Lichrosorb SI 60 silica (10 μm) and an Altex 110A pump. M.p.s were determined on a Buchi 510 apparatus, and are uncorrected.

THF refers to tetrahydrofuran, freshly distilled off lithium aluminium hydride using triphenylmethane as an indicator. Ether was dried by distillation off sodium wire and stored over sodium. DMF refers to dimethylformamide distilled off 4 Å molecular sieves and stored over 4 Å sieves. EtOAc was distilled before use. BuLi refers to 1.6M butyl-lithium in hexane. All non-aqueous reactions were carried out under a dry nitrogen atmosphere.

N-(1-*Diphenylphosphinoyl*-2-*methylpropan*-2-*yl*)*benzamide* (**25**).—Sulphuric acid (98%) (8 ml) was added dropwise to a stirred solution of 1-diphenylphosphinoyl-2-methylpropan-2-ol[31] (100 g, 36.5 mmol) and benzonitrile (3.8 ml, 36.5 mmol) in TFA (20 ml) in an ice-bath, such that the internal temperature remained below 35 °C. The reaction was heated at 60 °C for 3.75 h, cooled, poured onto ice (*ca.* 100 g) and left overnight; it was then extracted into CH_2Cl_2 (3 × 100 ml), and the extract dried ($MgSO_4$), and evaporated under reduced pressure to give a colourless oil which crystallised slowly with time and was recrystallised to give the amide (9.75 g, 71%) as microcrystalline prisms, m.p. 114—115 °C (from EtOAc), R_F (Et_2O) 0.16; $\nu_{max.}$(Nujol) 3 350 (NH), 1 640 (C=O I), 1 535 (C=O II), 1 437 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.25—7.95 (16 H, m, Ph and NH), 2.83 (2 H, d, *J* 11 Hz, PCH_2), and 1.55 (6 H, s, Me) (Found: M^+, 377.1532. $C_{23}H_{24}NO_2P$ requires *M*, 377.1545); *m/z* 377 (0.75%), 215 (100, $Ph_2PO{\cdot}CH_2^+$), and 105 (33, $PhCO^+$).

1-*Diphenylphosphinoylpropan*-2-*ylamine* (**11**).—A solution of diphenylphosphinoylacetone[18] (24.3 g), ammonium acetate (recrystallised from EtOH) (81.3 g), and sodium cyanoborohydride (4.2 g) in dry MeOH (1.25 l) was stirred for 48 h at room temperature; it was then evaporated under reduced pressure, diluted with water (500 ml), and the solution extracted with CH_2Cl_2 (3 × 200 ml). The combined organic layers were

extracted with 0.1M HCl (3 × 200 ml), adjusted to pH 11 with 2M sodium hydroxide, and extracted with CH_2Cl_2 (3 × 200 ml); the organic layers were dried ($MgSO_4$) and evaporated under reduced pressure to give a semicrystalline solid which was recrystallised to give the *amine* (20.43 g, 84%), as prisms, m.p. 83—86 °C (from EtOAc), R_F (EtOAc–Pr^iOH—Et_3N, 80:17:3) 0.05; $\nu_{max.}$($CDCl_3$) 3 370, 3 300 (NH), and 1 440 cm^{-1} (PPh); δ($CDCl_3$) 7.30—7.98 (10 H, m, Ph_2PO), 3.25—3.62 (1 H, m, CHN), 2.31 (2 H, dd, J_{PH} 11, J_{HH} 6 Hz, PCH_2), 1.85 (2 H, s, NH_2), and 1.16 (3 H, d, *J* 6 Hz, Me) (Found: M^+, 259.1118. $C_{15}H_{18}NOP$ requires *M*, 259.1126); *m/z* 259 (0.59%), 244 (11, *M* − Me). 215 [99, $Ph_2P(O)CH_2^+$], 201 (53, Ph_2PO^+), and 59 (100, *M* − Ph_2PO).

N-(1-*Diphenylphosphinoylpropan-2-yl*)*benzamide* (**26**).—Benzoyl chloride (3.08 ml, 26.5 mmol) in CH_2Cl_2 (50 ml) was added dropwise to a stirred solution of the amine (**25**), (6.9 g, 26.5 mmol) and Et_3N (3.7 ml, 26.5 mmol) in CH_2Cl_2 (100 ml) at room temperature. After 30 min, water (100 ml) was added, the layers shaken and separated, the aqueous layer washed with CH_2Cl_2 (2 × 50 ml), and the combined organic layers dried ($MgSO_4$) and evaporated under reduced pressure to give a white solid which was recrystallised to give the *amide* (**26**) (7.80 g, 83%), as microcrystalline prisms, m.p. 175—175.5 °C (from EtOAc) (Found: C, 72.5; H, 6.10; N, 3.9. $C_{22}H_{22}NO_2P$ requires C, 72.8; H, 6.05; N, 3.85%), R_F (EtOAc), 0.20; $\nu_{max.}$(Nujol) 3 250 (NH), 1 640 (C=O I), 1 540 (C=O II), 1 440 (P–Ph), and 1 170 cm^{-1} (P=O); δ($CDCl_3$) 7.30—7.97 (16 H, m, Ph and NH), 4.23—4.78 (1 H, m, CHN), 2.55 (2 H, dd, J_{HP} 6 Hz, PCH_2), and 1.35 (3 H, d, *J* 7 Hz, Me) (Found: M^+, 363.1440. $C_{22}H_{22}NO_2P$ requires *M*, 363.1439); *m/z* 363 (4.7%), 362 (10, *M* − H), 215 [100, $Ph_2P(O)CH_2^+$], and 202 (57, Ph_2POH^+).

1-(2-*Diphenylphosphinoylpropyl*)*piperidine* (**13**).—(i) *By Mannich reaction.* A solution of 3-diphenylphosphinoylpropionic acid[32] (**12**) (4.0 g), piperidine (4.0 ml), and formalin (37% w/v) (0.4 ml) in dioxane (25 ml) was heated at 40 °C for 20 h and then at 65 °C for 60 h; it was then cooled and evaporated under reduced pressure. Piperidine (5 ml) and water (12 ml) were added and the resulting solution heated under reflux for 20 h, cooled, and diluted with water (50 ml). The solution was extracted with CH_2Cl_2 (3 × 50 ml) and the combined organic layers were washed with 0.1M HCl (2 × 75 ml). The pH of the combined aqueous layers was adjusted to 11, after which they were extracted with CH_2Cl_2 (3 × 50 ml), and the combined extracts dried ($MgSO_4$), and evaporated under reduced pressure to give the *amine* (1.9 g, 40%) as needles, m.p. 149—149.5 °C (from EtOAc) (Found: C, 73.0; H, 7.9; N, 4.7. $C_{20}H_{26}NOP$ requires C, 73.1; H, 7.9; N, 4.6%); $\nu_{max.}$($CDCl_3$) 1 440 (P–Ph) and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.35—7.87 (10 H, m, Ph_2PO), 2.15—2.50 (7 H, m, PCH and NCH_2), and 0.98—1.32 (9 H, m, $CH_2CH_2CH_2$ and Me); *m/z* 327 (6%, M^+), 242 (18, *M* − $C_5H_{10}N$), 202 (52, Ph_2POH^+), and 201 (100, Ph_2PO^+).

(ii) *By methylation of compound* (**5**). BuLi (1.92 ml) was added to a stirred solution of the amine (**5**) (0.94 g) in THF (50 ml) at 0 °C and stirring was continued for 15 min. The vessel was cooled to −10 °C, methyl iodide (0.206 ml) was added, stirring was continued for 1 h, and work-up gave the amine (**13**) (0.81 g, 83%).

N-(2-*Diphenylphosphinoylethyl*)*benzamide* (**24**).—Sodium hydride (50% oil dispersion; 0.83 g) was added to a stirred solution of diphenyl vinyl phosphine oxide[33] (3.14 g) and benzamide (1.71 g) in DMF (100 ml) in an ice-bath and stirring continued overnight whilst allowing the solution to warm to room temperature. Aqueous ammonium chloride (10 ml) was added and the solvent evaporated under reduced pressure (oil pump); water (100 ml) was then added and the solution extracted with CH_2Cl_2 (3 × 75 ml). The combined organic layers were dried ($MgSO_4$) and evaporated under reduced pressure and the residue purified by column chromatography (Et_2O then EtOAc then EtOAc–MeOH, 90:10) to give the *amide* (3.5 g, 71%) as prisms, m.p. 103—104 °C (from EtOAc), R_F (EtOAc) 0.15; $\nu_{max.}$($CDCl_3$) 3 300 (NH), 1 640 (C=O I), 1 530 (C=O II), 1 430 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 8.46 (1 H, t, *J* 5.5 Hz, NH), 7.20—8.00 (15 H, m, Ph), 3.82 (2 H, ddt, J_{PH} 14, J_{HH} 5.5, 6.5 Hz, NCH_2), and 2.68 (2 H, dt, J_{PH} 11, J_{HH} 6.5 Hz, PCH_2) (Found: M^+, 349.1224. $C_{21}H_{20}NO_2P$ requires *M*, 349.1231); *m/z* 349 (0.12%), 228 [50, $Ph_2P(O)CHCH_2^+$], 202 (94, Ph_2POH^+), 122 (100, $PhCONH_3^+$), and 105 (79, $PhCO^+$).

N-(2-*Diphenylphosphinoylpropyl*)*benzamide* (**42**).—BuLi (14.3 ml) was added to a stirred solution of the amide (**24**) (4.0 g) in LiBr-saturated THF (100 ml) at −40 °C and stirring continued for 15 min. The solution was then cooled to −78 °C and methyl iodide (0.69 ml) added dropwise; stirring was then continued while the solution warmed to −30 °C over 30 min. Aqueous ammonium chloride (5 ml) followed by water (100 ml) were added to the mixture which was then extracted with CH_2Cl_2 (3 × 75 ml). The combined organic layers were dried ($MgSO_4$) and evaporated under reduced pressure, and the residue was recrystallised (EtOAc–MeOH) to give the *amide* (3.32 g, 80%) as prisms, m.p. 220—221 °C (from EtOAc–MeOH) (Found: C, 70.8; H, 6.1; N, 3.9. $C_{22}H_{22}NO_2P$ requires C, 70.9; H, 5.90; N, 3.8%); R_F (EtOAc–Et_3N, 97:3) 0.22; $\nu_{max.}$(Nujol) 3 200 (NH), 1 660 (C=O I), 1 530 (C=O II), 1 430 (P–Ph), and 1 175 cm^{-1} P=O); δ($CDCl_3$) 7.33—8.05 (16 H, m, Ph and NH), 3.28—4.18 (2 H, m, NCH_2), 2.60—3.04 (1 H, m, PCH), and 1.13 (3 H, dd, J_{HH} 7.5, J_{HP} 16 Hz, Me) (Found: M^+, 363.1382. $C_{22}H_{22}NO_2P$ requires *M*, 363.1388); *m/z* 363 (14, M^+), 230 [59, $Ph_2P(O)CH_2Me^+$], 202 (89, Ph_2POH^+), 105 (100, $PhCO^+$), and 77 (100, Ph^+).

N-(3-*Diphenylphosphinoylbutan-2-yl*)*benzamide* (**33**).—Similarly, the amide (**26**) (3.63 g) in LiBr-saturated THF (80 ml) with BuLi (13.4 ml) and methyl iodide (0.62 ml) gave an oil which crystallised and was recrystallised (EtOAc), and the mother liquors flash chromatographed (EtOAc–Et_3N, 97:3) to give the *amide* as a single diastereoisomer (total 2.94 g, 78%) as prisms, m.p. 177—178 °C (from EtOAc) (Found: C, 73.4; H, 6.45; H, 4.0. $C_{23}H_{24}NO_2P$ requires C, 73.2; H, 6.35; N, 3.7%); R_F (EtOAc–Et_3N, 97:3) 0.37; $\nu_{max.}$(Nujol) 3 250 (NH), 1 640 (C=O I), 1 550 (C=O II), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.33—8.03 (16 H, m, Ph and NH), 4.16—4.60 (1 H, m, CHN), 2.70—3.10 (1 H, m, PCH), 1.36 (3 H, d, *J* 7.5 Hz, MeCHN), and 1.30 (3 H, dd, J_{HH} 7.5, J_{HP} 16 Hz, PCHMe) (Found: M^+, 377.1543. $C_{23}H_{24}NO_2P$ requires *M*, 377.1545); *m/z* 377 (5%), 230 [100, $Ph_2P(O)CH_2Me^+$], 202 (40, Ph_2POH^+), and 105 (80, $PhCO^+$).

N-(2-*Diphenylphosphinoylethyl*)-N-*methylbenzamide* (**23**).—A mixture of vinyldiphenylphosphine oxide[33] (0.2 g) and a solution (33% w/v) of methylamine in ethanol (10 ml) was heated in a sealed tube under reflux (oil-bath 100 °C) for 24 h, and then cooled and the solvent removed under reduced pressure. The crude product, R_F (EtOAc–Et_3N, 97:3) 0.02, was dissolved in CH_2Cl_2 (10 ml) and Et_3N (1 ml); benzoyl chloride (0.11 g) was added, and the solution was stirred at room temperature overnight. The solvent was removed under reduced pressure and the resultant oil purified by p.l.c. (EtOAc), giving, as the main product, an oil (0.28 g, 88%) R_F(EtOAc) 0.2; δ($CDCl_3$) 7.0—7.9 (15 H, m, Ph), 3.5—3.9 (2 H, m, NCH_2), 3.0 (3 H, s, NMe), and 2.5—2.9 (2 H, m, PCH_2) identified as the amide (**23**).

3-*Diphenylphosphinoyl*-2-*methylpent*-4-*en*-2-*ol* (**8**).—Allyldiphenylphosphine oxide (**12**) (726 mg) and BuLi (2.0 ml) in LiBr-

saturated THF (25 ml) and acetone (0.4 ml) gave, after quenching with aqueous ammonium chloride (5 ml) and work-up followed by flash chromatography (EtOAc), the *alcohol* (602 mg, 67%) as needles, m.p. 144—145 °C (from EtOAc) (Found: C, 71.7; H, 7.10. $C_{18}H_{21}PO_2$ requires C, 72.0; H, 7.00%), R_F (EtOAc) 0.45; $\nu_{max.}$(KBr) 3 430 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.42—8.00 (10 H, m, Ph_2PO), 5.62—6.05 (1 H, m, CH=CH_2), 4.86—5.20 (3 H, m, CH_2=CH and OH), 3.55 (1 H, dd, *J* 10, 11 Hz, PCH), and 1.27 (6 H, s, Me); *m/z* 301 (0.47%, MH^+), 285 (10, *M* − Me), 242 [94, $Ph_2P(O)CH_2$-$CHCH_2^+$], 219 (21, $Ph_2PO_2H_2^+$), and 201 (100, Ph_2PO^+).

Attempted Michael Addition to the Alcohol (**8**).—The alcohol (**8**) (0.65 g), water (7 ml), and piperidine (3.5 ml) were heated under reflux for 15 h after which the solvent was evaporated and the product purified by column chromatography. The major component was identified as the amine (**5**) by n.m.r. and t.l.c.

3-*Diphenylphosphinoyl*-2-*methyl*-4-*piperidinobutan*-2-*ol* (**14b**).—BuLi (2.35 ml, 3.40 mmol) was added dropwise to a stirred solution of 1-(2-diphenylphosphinoylethyl)piperidine (**5**) (1.0 g, 3.18 mmol) in LiBr-saturated Et_2O (25 ml) at 0 °C, and stirring continued for 30 min, thereby forming a yellow solution of the anion. The flask was cooled to −78 °C, dry acetone (0.3 ml, 4.5 mmol) was added slowly, and stirring continued for 15 min. The reaction was quenched with saturated aqueous ammonium chloride and allowed to warm to room temperature. Water (100 ml) was added and the solution extracted into CH_2Cl_2 (3 × 100 ml), dried ($MgSO_4$), and evaporated under reduced pressure to give, after flash chromatography [22] (EtOAc–Et_3N, 97:3) the *alcohol* (0.88 g, 75%) as needles, m.p. 147—148 °C (decomp.) (from EtOAc) (Found: C, 71.2; H, 8.2; N, 3.7. $C_{22}H_{30}NO_2P$ requires C, 71.2; H, 8.1; N, 3.7%); R_F (EtOAc–Pr^iOH–Et_3N, 80:17:3) 0.54; $\nu_{max.}$($CDCl_3$) 3 100 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.34—8.06 (10 H, m, Ph_2PO), 2.75—3.03 and 2.08–2.57 (7 H, m, NCH_2 and PCH), 1.16—1.70 (9 H, m, $NCH_2CH_2CH_2$ and Me), and 1.05 (3 H, s, Me); *m/z* (CI) 372 (1%, MH^+), 354 ($MH - H_2O$), 219 (70, $Ph_2PO{\cdot}OH_2^+$), and 153 (100, $MH - Ph_2PO_2H$).

1-(1-*Diphenylphosphinoyl*-2-*piperidinoethyl*)*cyclohexanol* (**14e**).—Similarly, the amine (**5**) (1.0 g), and BuLi (2.35 ml) in LiBr-saturated Et_2O (25 ml) with cyclohexanone (0.32 ml) gave, after chromatography (EtOAc–Et_3N, 97:3), the *alcohol* (1.01 g, 77%) as needles, m.p. 150—115 °C (decomp.) (from CH_2Cl_2–Et_2O) (Found: C, 73.1; H, 8.4; N, 3.4. $C_{25}H_{34}NO_2P$ requires C, 73.0; H, 8.3; N, 3.4%); R_F (EtOAc–Pr^iOH–Et_3N, 80:17:3) 0.63; $\nu_{max.}$($CDCl_3$) 3 350 (OH), 1 440 (P–Ph), and 1 175 cm^{-1} (P=O); δ($CDCl_3$) 7.35—8.10 (10 H, m, Ph_2PO), 6.6—7.0 (1 H, br s, OH), and 2.67—3.17 (16 H, m, CH_2); *m/z* (CI) 412 (2%, MH^+), 229 (13, $Ph_2P{\cdot}CHMe^+$), 86 (23, $C_5H_{10}NH_2^+$), and 52 (100).

3-*Diphenylphosphinoyl*-2-*methyl*-4-*pyrrolidin*-1-*ylbutan*-2-*ol* (**14a**).—Similarly, 1-(2-diphenylphosphinoylethyl)pyrrolidine [15] (**4**) (1.0 g) and BuLi (2.46 ml) in LiBr-saturated Et_2O (25 ml) with acetone (0.25 ml) gave, after chromatography, the *alcohol* as needles, m.p. 145—146 °C (decomp.) (from CH_2Cl_2–Et_2O) (Found: C, 70.6; H, 7.65; N, 4.0. $C_{21}H_{28}NO_2P$ requires C, 70.3; H, 7.85; N, 4.0); R_F (EtOAc–Et_3N, 97:3) 0.35; $\nu_{max.}$($CDCl_3$) 3 150 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.32—8.08 (10 H, m, Ph_2PO), 2.18—3.40 (7 H, m, PCH and NCH_2), 1.56—1.86 (4 H, m, NCH_2CH_2), 1.45 (3 H, s, Me), and 1.05 (3 H, s, Me); *m/z* 229 (23%, $Ph_2POCHCH_3^+$), 201 (19, Ph_2PO^+), 155 (72, *M* − Ph_2POH), 140 (100, MH^+ − Ph_2PO_2H), and 84 (74, $C_4H_8NCH_2^+$).

1-(1-*Diphenylphosphinoyl*-2-*pyrrolidin*-1-*ylethyl*)*cyclohexanol* (**14d**).—Similarly, the amine (**4**) (1.0 g, and BuLi (2.46 ml) in LiBr-saturated Et_2O (25 ml) with cyclohexanone (0.32 ml) gave, after chromatography, the *alcohol* (0.93 g, 70%) as needles, m.p. 142—114 °C (decomp.) (from CH_2Cl_2–Et_2O) (Found: C, 72.5; H, 8.15; N, 3.7. $C_{24}H_{32}NO_2P$ requires C, 72.5; H, 8.05; N, 3.5%); R_F (EtOAc–Pr^iOH–Et_3N, 80:17:3) 0.54; $\nu_{max.}$($CDCl_3$) 3 100 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.61—8.10 (10 H, m, Ph_2PO), 2.16—3.45 (7 H, m, NCH_2 and PCH), and 0.88—1.96 (14 H, m, CH_2); *m/z* 202 (30%, Ph_2POH^+), 195 (54, *M* − Ph_2POH), 98 (89, $C_6H_{10}O^+$), and 84 (100, $C_4H_{10}NCH_2^+$).

3-*Diphenylphosphinoyl*-2-*methyl*-4-*morpholinobutan*-2-*ol* (**14c**).—Similarly, 1-(2-diphenylphosphinoylethyl)morpholine (**6**) (1.0 g) and BuLi (2.35 ml) in LiBr-saturated Et_2O (50 ml) with acetone (0.3 ml) gave, after chromatography, (EtOAc–Et_3N, 97:3) the *alcohol* (0.77 g, 65%), as needles, m.p. 162—163 °C (from CH_2Cl_2–Et_2O) (Found: C, 67.2; H, 7.65; N, 3.0. $C_{21}H_{28}NO_3P$ requires C, 67.5; H, 7.5; N, 3.8%); R_F (EtOAc–Et_3N, 97:3) 0.32; $\nu_{max.}$(KBr) 3 400 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P–O); δ($CDCl_3$) 7.38—8.00 (10 H, m, Ph_2PO), 6.6 (1 H, br s, OH), 3.54—3.64 (4 H, br t, *J* 4.5 Hz, OCH_2), 2.27—2.95 (7 H, m, NCH_2 and PCH), 1.44 (3 H, s, Me), and 1.12 (3 H, s, Me); *m/z* (CI) 374 (7%, MH^+), 229 (20, $Ph_2POCHMe^+$). 156 (60, $MH - Ph_2PO_2H$), 88 (90, $OC_4H_8NH_2^+$), and 52 (100).

1-(1-*Diphenylphosphinoylmorpholin*-2-*ylethyl*)*cyclohexanol* (**14f**).—Similarly, the amine (**6**) (1.0 g), and BuLi (2.35 ml) in LiBr-saturated Et_2O (50 ml) and cyclohexanone (0.32 ml) gave, after chromatography, the alcohol (0.89 g, 68%) as needles, m.p. 145—146 °C (decomp.) (from Pr^iOH–hexane) (Found: C, 69.7; H, 7.85; N, 3.5. $C_{24}H_{32}NO_3P$ requires C, 69.7; H, 7.75; N, 3.4%); R_F (EtOAc–Et_3N, 97:3) 0.52; $\nu_{max.}$($CDCl_3$) 3 300 (OH), 1 440 (P–Ph), and 1 170 cm^{-1} (P–O); δ($CDCl_3$) 7.33—8.08 (10 H, m, Ph_2PO), 5.85 (1 H, br s, OH), 3.57 (4 H, t, *J* 4.5 Hz, OCH_2), 1.95—3.09 (7 H, m, NCH_2 and PCH), and 1.00—1.95 (10 H, m, CH_2); *m/z* 395 (0.31%, *M* − H_2O), 211 (93, *M* − Ph_2POH), 194 (60, *M* − Ph_2POCH_2), and 100 (100, $OC_4H_8NCH_2^+$).

The following were prepared as mixtures of diastereoisomers which were separated by chromatography (Table 2).

3-*Diphenylphosphinoyl*-4-*piperidinobutan*-2-*ol* (**16a**).—Similarly, the amine (**5**) (1.0 g) and BuLi (2.35 ml) in LiBr-saturated THF (40 ml) with acetaldehyde (0.3 ml) gave, after flash chromatography (EtOAc–Et_3N, 97:3), the alcohols (**16a**) which were separated by h.p.l.c. (EtOAc–Et_3N–hexane, 85:3:12). The first compound to be eluted was the *alcohol threo*-(**16a**) (0.401 g, 35%), as needles, m.p. 173.5—174.5 °C (decomp.) (from CH_2Cl_2–Et_2O) (Found: C, 70.3; H, 7.85; N, 3.9. $C_{21}H_{28}NO_2P$ requires C, 70.6; H, 7.85; N, 3.9%); R_F (EtOAc–Pr^iOH–Et_3N, 80:17:3) 0.50; $\nu_{max.}$($CDCl_3$) 3 400 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.39—7.94 (10 H, m, Ph_2PO), 4.25 (1 H, br s, OH), 4.00 (1 H, m, CHOH), 3.14—3.30 (2 H, m, NCH_AH_BCHP), 2.10—2.68 (5 H, m, NCH_ACH_B and NCH_2-CH_2), and 1.17—1.68 (9 H, m, $NCH_2CH_2CH_2$ and Me) (Found: M^+, 357.1865. $C_{12}H_{28}NO_2P$ requires *M*, 357.1857); *m/z* 357 (0.6%), 312 (0.7, *M* − MeCHO − H), 202 (8, Ph_2-POH^+), 201 (11, Ph_2PO^+), 156 (39, *M* − Ph_2PO), and 155 (100, *M* − Ph_2POH); the second to elute was the *alcohol erythro*-(**16a**) (0.386 g, 34%), as needles, m.p. 158.5—159.5 °C (decomp.) (from CH_2Cl_2–Et_2O) (Found: C, 70.6; H, 7.95; N, 3.9. $C_{12}H_{28}NO_2P$ requires C, 70.7; H, 7.85; N, 3.9%); R_F (EtOAc–Pr^iOH–Et_3N, 80:17:3) 0.50; $\nu_{max.}$($CDCl_3$) 3 400 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.38—7.99 (10 H, m, Ph_2PO), 5.5 (1 H, br s, OH), 4.30 (1 H, q, *J* 6 Hz, CHOH), 2.10—2.96 (7 H, m, NCH_2 and PCH), 1.21—1.60 (6 H, m, NCH_2-CH_2CH_2), and 1.07 (3 H, d, *J* 6 Hz, Me) (Found: M^+, 357.1835. $C_{21}H_{28}NO_2P$ requires *M*, 357.1858); *m/z* 357 (0.2%), 314 (0.4,

*M*H − MeCHO), 202 (5, Ph_2POH^+), 201 (9, Ph_2PO^+), 155 (100, *M* − Ph_2POH), and 140 (63, *M* − Ph_2PO_2).

3,4-*Dimethyl*-2-*diphenylphosphinoyl*-1-*piperidinopentan*-3-*ol* (**21**).—Similarly, the amine (**5**) (1.0 g) and BuLi (2.35 ml) in LiBr-saturated THF (40 ml) with 3-methylbutan-2-one (0.3 ml) gave, after flash chromatography, (EtOAc–hexane–Et_3N, 85:12:3) the *alcohol threo*-(**21**) as the first compound to be eluted from the column (367 mg, 28.8%), as needles, m.p. 121—124 °C (decomp.) (from CH_2Cl_2–Et_2O) (Found: C, 70.6; H, 8.5; N, 3.2. $C_{24}H_{34}NO_2P$ requires C, 70.6; H, 8.6; N, 3.4%); R_F (EtOAc–Et_3N, 97:3) 0.53; $\nu_{max.}$($CDCl_3$) 3 300 (OH), 1 440 (P–Ph), and 1 170 cm^{-1} (P=O); δ($CDCl_3$) 7.20—8.01 (10 H, m, Ph_2PO), 5.7 (1 H, br s, OH), 2.9—3.21 (1 H, m, PCH), 1.10—2.55 (13 H, m, CH_2s and Me_2CH), 1.19 (3 H, s, *Me*COH), 0.90 (3 H, d, *J* 7 Hz, *Me**CH), and 0.80 (3 H, d, *J* 7 Hz, *Me*CH) (Found: M^+, 399.2334. $C_{24}H_{34}NO_2P$ requires *M*, 399.2327); *m*/*z* 399 (0.08%), 356 (7, *M* − Pr^i), 313 (7), 229 (10, $Ph_2PO{\cdot}C_2H_4^+$), and 201 (34, Ph_2PO^+); the second compound to be eluted from the column was the *alcohol erythro*-(**21**) (92 mg, 7.2%), as needles, m.p. 138—139 °C (decomp.) (from CH_2Cl_2–Et_2O) (Found: C, 72.5; H, 8.6; N, 3.7. $C_{24}H_{34}NO_2P$ requires C, 72.2; H, 8.5; N, 3.5%); R_F (EtOAc–Et_3N, 97:3) 0.35; $\nu_{max.}$($CDCl_3$) 3 300 (OH), 1 440 (P–Ph), and 1 175 cm^{-1} (P=O); δ($CDCl_3$) 7.30—8.00 (10 H, m, Ph_2PO), 6.5 (1 H, br s, OH), 1.95—3.30 (7 H, m, PCH, NCH_2), 1.21—1.70 (7 H, m, $NCH_2CH_2CH_2$ and Me_2CH), 1.34 (3 H, s, *Me*COH), 0.86 (3 H, d, *J* 6 Hz, *Me*CH), and 0.77 (3 H, d, *J* 6 Hz, *Me*CH); *m*/*z* 399 (3%, M^+) 229 [32, $Ph_2P(O)C_2H_4^+$], 197 (58, *M* − Ph_2POH), 180 (30, *M* − Ph_2PO_2H), 98 (10, $C_5H_{10}NCH_2^+$), and 86 (30, $C_5H_{10}NH_2^+$).

In a similar experiment, 3-methylbutan-2-one (1.4 ml) was added to a stirred solution of the amine (**5**) (3.13 g) and BuLi (6.8 ml) in LiBr-saturated THF (70 ml) at −50 °C to give *threo*-(**21**) (1.39 g, 34.5%) and *erythro*-(**21**) (0.56 g, 11.5%).

2-*Diphenylphosphinoyl*-3-*methyl*-1-*pyrrolidin*-1-*ylhexan*-3-*ol* (**19**).—Similarly, the amine (**4**) (1.5 g) and BuLi (3.4 ml) in LiBr-saturated THF (50 ml) with pentan-2-one (0.57 ml) gave, after flash chromatography (EtOAc–hexane–Et_3N, 85:12:3), the *alcohol threo*-(**19**) as the first compound to be eluted from the column (873 mg, 45.5%), as needles, m.p. 155.5—156.5 °C (decomp.) (from EtOAc) (Found: C, 71.3; H, 8.1; N, 3.8. $C_{23}H_{32}NO_2P$ requires C, 71.5; H, 8.3; N, 3.6%); R_F (EtOAc–Et_3N, 97:3) 0.34; $\nu_{max.}$($CDCl_3$), 3 300 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$), 7.35—8.17 (10 H, m, Ph_2PO), 6.95 (1 H, br s, OH), 2.17—3.20 (7 H, m, NCH_2 and PCH), 1.15—1.95 (8 H, m, CH_2), 1.06 (3 H, s, MeCOH), and 0.85 (3 H, br t, *J* 7 Hz, $MeCH_2$); *m*/*z* 229 [52%, $Ph_2P(O)C_2H_4^+$], 201 (85, Ph_2PO^+), and 183 (100, *M* − Ph_2POH); the second compound to be eluted from the column was the *alcohol erythro*-(**12**) (342 mg, 18%), as needles, m.p. 146.5—147.5 °C (decomp.) (from EtOAc), R_F (EtOAc–Et_3N, 97:3) 0.14; $\nu_{max.}$($CDCl_3$) 3 300 (OH), 1 400 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.35—8.10 (11 H, m, Ph_2PO and OH), 2.23—3.47 (7 H, m, PCH and NCH_2), 1.50—1.85 (4 H, m, NCH_2CH_2), 1.36 (3 H, s, *Me*COH), 1.00—1.34 (4 H, m, $MeCH_2CH_2$), and 0.56 (3 H, br t, *J* 6.5 Hz, $MeCH_2$) (Found: M^+ − Me, 370.1950. $C_{22}H_{19}NO_2P$ requires *M* − Me, 370.1936); *m*/*z* 370 (0.14%), 342 (0.5, *M* − Pr), 229 [19, $Ph_2P(O)C_2H_4^+$], 201 (10, Ph_2PO^+), 183 (38, *M* − Ph_2POH), and 140 (100, *M* − Ph_2POH − Pr).

The following were prepared as mixtures of diastereoisomers which were separated by fractional recrystallisation.

2-*Diphenylphosphinoyl*-1-*phenyl*-3-*piperidinopropan*-1-*ol* (**16b**).—Similarly, the amine (**5**) (3.13 g), and BuLi (6.7 ml) in THF (70 ml) with benzaldehyde (1.02 ml) gave, after chromatography, the alcohols (**16b**) (3.34 g, 80%); a portion of the mixture was separated by fractional recrystallisation (EtOAc) giving the less soluble *alcohol threo*-(**16b**) (0.50 g), as needles, m.p. 174—175 °C (decomp.) (from EtAOc) (Found: C, 74.4; H, 7.4; N, 3.2. $C_{26}H_{30}NO_2P$ requires C, 74.4; H, 7.2; N, 3.3%); R_F (EtOAc–Et_3N, 97:3) 0.42; $\nu_{max.}$($CDCl_3$) 3 050 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.10—8.03 (15 H, m, Ph), 6.5 (1 H, br s, OH), 5.20 (1 H, d, J_{HH} 4 Hz, J_{PH} 10 Hz, *CH*OH), 3.12—3.50 (1 H, m, PCH), 1.96—2.85 (6 H, m, NCH_2), and 1.20—1.63 (6 H, m, $NCH_2CH_2CH_2$) (Found: M^+, 419.2014. $C_{26}H_{30}NO_2P$ requires *M*, 419.2014); *m*/*z* 419 (0.65%), 312 (8, *M* − PhCHOH), 229 (17, $Ph_2P(O)C_2H_4^+$), 218 (37, *M* − Ph_2PO), 217 (100, *M* − Ph_2POH), and 200 (62, *M* − Ph_2PO_2H); the mother liquors gave the more soluble *alcohol erythro*-(**16b**) (0.47 g), as needles, m.p. 144.5—146.5 °C (decomp.) (from EtOAc); R_F (EtOAc–Et_3N, 97:3) 0.42; $\nu_{max.}$ 3 050 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.00—7.98 (15 H, m, Ph), 6.8 (1 H, br s, OH), 5.31 (1 H, dd, J_{HH} 4.5 Hz, J_{PH} *CH*OH), 2.43—3.16 (3 H, m, $PCHCH_2N$), 1.97—2.20 (4 H, m, NCH_2CH_2), and 1.20—1.40 (6 H, m, $NCH_2CH_2CH_2$) (Found: M^+, 419.2002. $C_{26}H_{30}NO_2P$ requires *M*, 419.1015); *m*/*z* 419 (0.34%), 312 (9), 219 (100, *M* − Ph_2POH), and 201 (30, Ph_2PO^+).

3-*Diphenylphosphinoyl*-4-*morpholinobutan*-2-*ol* (**16c**).—Similarly, the amine (**6**) (1.575 g) and BuLi (3.25 ml) in LiBr-saturated THF (50 ml) with acetaldehyde (50 ml) gave, after flash chromatography, the alcohols (**16c**) 1.35 g, 75%) which were separated by fractional recrystallisation (EtOAc) to give the less soluble *alcohol threo*-(**16c**) (0.64 g), as needles, m.p. 198—199 °C (decomp.) (from EtOAc) (Found: C, 66.7; H, 7.3; N, 4.0. $C_{20}H_{26}NO_3P$ requires C, 66.9; H, 7.25; N, 3.9%); R_F (EtOAc–Et_3N, 97:3) 0.17; $\nu_{max.}$($CDCl_3$) 3 300 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.38—8.00 (10 H, m, Ph_2PO), 5.7 (1 H, br s, OH), 4.03 (1 H, br quintet, *J* 6 Hz, *CH*OH), 3.63 (4 H, t, *J* 4.5 Hz, CH_2O), 3.00—3.52 (3 H, m, $PCHCH_2N$), 2.13—2.79 (4 H, m, NCH_2CH_2), and 1.39 (3 H, d, *J* 6 Hz, *Me*CH) (Found: MH^+, 360.1743. $C_{20}H_{27}NO_3P$ requires *M*H, 360.1728); *m*/*z* 360 (0.39%), 315 (0.5, *M* − MeCHO), 229 [13, $Ph_2P(O)C_2H_4^+$], 202 (12, Ph_2POH^+), 201 (13, Ph_2P^+), 157 (60, *M* − Ph_2POH), 140 (100, *M* − Ph_2PO_2H), and 100 (69, $OC_4H_8NCH_2^+$); the mother liquors gave the more soluble *alcohol erythro*-(**16c**) (0.65 g), as needles, m.p. 157—158 °C (from EtOAc) (Found: C, 66.5; H, 7.45; N, 3.9. $C_{20}H_{26}NO_3P$ requires C, 66.9; H, 7.25; N, 3.9%); R_F (EtOAc–Et_3N, 97:3) 0.17; $\nu_{max.}$($CDCl_3$) 3 300 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.32—8.03 (10 H, m, Ph_2PO), 5.28 (1 H, br s, OH), 4.20—4.53 (1 H, m, *CH*OH), 3.47 (4 H, t, *J* 4.5 Hz, OCH_2), 2.30—3.15 (3 H, m, $PCHCH_2N$), 2.26 (4 H, br t, *J* 4.5 Hz, NCH_2CH_2), and 1.6 (3 H, d, *J* 6 Hz, *Me*CH) (Found: M^+ − H, 358.1564. $C_{20}H_{25}NO_3P$ requires *M* − H, 358.1572); *m*/*z* 358 (0.06%), 341 (0.1, *M* − H_2O), 314 (0.1), 229 [20, $Ph_2P(O)C_2N_4^+$], 202 (21, Ph_2POH^+), 201 (22, Ph_2PO^+), 158 (38, *M* − Ph_2POH), and 157 (100, *M* − Ph_2PO).

2-*Diphenylphosphinoyl*-4-*pyrrolidin*-1-*ylbutan*-2-*ol* (**16e**).—Similarly, the amine (**4**) (1.5 g), BuLi (3.6 ml), and acetaldehyde (0.37 ml, excess) in THF saturated with LiBr gave a mixture of alcohols (**16e**) (1.35 g, 79%) which could not be separated by chromatography. The ratio of isomers was estimated as 50:50 from the n.m.r. spectrum.

2-*Diphenylphosphinoyl*-3-*morpholino*-1-*phenylpropan*-1-*ol* (**16d**).—Similarly, the amine (**6**) (3.15 g), and BuLi (6.6 ml) in THF (70 ml) with benzaldehyde (1.02 ml) gave, after flash chromatography, the alcohols (**16d**) (3.24 g, 77%) which were separated by fractional recrystallisation (EtOAc) giving the less soluble *alcohol threo*-(**16d**) (1.29 g) as needles, m.p. 181—182 °C (decomp.) (from EtAOc) (Found: C, 71.1; H, 6.9; N, 3.5. $C_{25}H_{28}NO_3P$ requires C, 71.3; H, 6.65; N, 3.4%); R_F (EtOAc–

Pr^iOH–Et_3N, 80:17:3) 0.48; $\nu_{max.}$($CDCl_3$) 3 300 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.10—7.97 (15 H, m, Ph), 6.5 (1 H, br s, OH), 5.18 (1 H, dd, J_{HH} 5 Hz, J_{PH} 13 Hz, C*H*OH), 3.50 (4 H, t, *J* 4.5 Hz, CH_2O), 2.93—3.38 (1 H, m, PCH), and 2.95—2.88 (6 H, m, NCH_2); *m/z* 403 (0.25%, *M* − H_2O), 314 (5), 219 (45, *M* − Ph_2POH), and 20 (100, Ph_2-POH); the mother liquors gave the more soluble *alcohol erythro*-(**16d**) (1.90 g), as needles, m.p. 144—146 °C (from EtOAc) (Found: C, 71.1; H, 7.1; N, 3.8. $C_{25}H_{28}NO_3P$ requires C, 71.3; H, 6.65; N, 3.4%); R_F (EtOAc–Pr^i–Et_3N, 80:17:3) 0.48; $\nu_{max.}$($CDCl_3$) 3 300 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.09—8.03 (15 H, m, Ph), 5.04 (1 H, br s, OH), 5.30 (1 H, dd, J_{HH} 2 Hz, J_{PH} 8 Hz, C*H*OH), 3.23 (4 H, t, *J* 4.5 Hz, CH_2O), 2.52—2.91 (3 H, m, $PCHCH_2N$), and 1.63—2.30 (4 H, m, NCH_2CH_2) (Found: MH^+, 422.1853. $C_{25}H_{29}NO_3P$ requires *M*H, 422.1885); *m/z* 422 (0.14%, MH^+), 405 (14, *M*H − OH), 314 (10, *M* − PhCHO − H), 229 [18, $Ph_2P(O)C_2H_4^+$], 219 (65, *M* − Ph_2POH), 202 (100, Ph_2POH), and 201 (16, Ph_2PO^+).

2-*Diphenylphosphinoyl*-3-*morpholino*-1-*phenylpropyl Dimethyl-t-butylsilyl Ether* (**18**).—A solution of the alcohols (**16d**) (2.97 g, 7.05 mmol), imidazole (1.18 g, 17.3 mmol), and dimethyl-t-butylsilyl chloride (1.27 g, 8.45 mmol) in DMF (7 ml) was stirred for 48 h at 45 °C. Water (100 ml) was added and the mixture was extracted with Et_2O (3 × 70 ml); the combined organic layers were washed with water (3 × 75 ml), dried ($MgSO_4$), and evaporated under reduced pressure to give, after flash chromatography (EtOAc–hexane–Et_3N, 85:12:3) followed by p.l.c. (Et_2O, double elution), *erythro*-(**18**) (2.11 g, 57%) as an oil, R_F (EtOAc–Et_3N, 97:3) 0.57; $\nu_{max.}$($CDCl_3$) 1 635 (aromatic C=C), 1 440 (P–Ph), and 1 190 cm^{-1} (P=O); δ($CDCl_3$) 6.98—7.38 and 7.62—7.95 (15 H, m, Ph), 5.00—5.35 (1 H, m, CHOSi), 2.40—3.63 (7 H, m, OCH_2 and NCH_2CHP), 1.60—2.40 (4 H, m, NCH_2CH_2), 0.78 (9 H, s, Me_3C), −0.10 (3 H, s, *Me*Si), and −0.42 (3 H, s, *Me*Si) (Found: M^+ − Me, 520.2430. $C_{30}H_{39}NO_3PSi$ requires *M* − Me, 520.2437); *m/z* 520 (0.6%, *M* − Me), 478 (25, *M* − Bu^t), 421 (2, *M*H − Bu^tMe_2Si), 333 (100, *M* − Ph_2POH), and 314 [36, $Ph_2P(O)CHCH_2NC_4H_8O^+$]; and *threo*-(**18**) (1.11 g, 29%), as an oil, R_F (EtOAc–Et_3N, 97:3) 0.52; $\nu_{max.}$($CDCl_3$) 1 440 (P–Ph) and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.22—7.60 and 7.65—8.20 (15 H, m, Ph), 5.39 (1 H, dd, J_{HH} 6 Hz, J_{PH} 10 Hz, CHOSi), 3.45 (4 H, t, *J* 4.5 Hz, OCH_2), 3.17 (1 H, ddt, J_{HH} 6.6 Hz, J_{PH} 12 Hz, PCH), 2.59 (2 H, dd, J_{HH} 6 Hz, J_{PH} 16 Hz, $PCHCH_2N$), 2.23 and 1.93 each (2 H, dt, J_{vic} 4.5 J_{gem} 12 Hz, NCH_2CH_2), 0.83 (9 H, s, Me_3C), −0.02 (3 H, s, *Me*Si), and −0.14 (3 H, s, *Me*Si) (Found: MH^+, 536.2746. $C_{31}H_{43}NOPSi$ requires *M*H, 536.2750); *m/z* 536 (0.08%), 478 (28, *M* − Bu^t), 379 (33, *M* − Bu^t − $CHNC_4H_8O$), 333 (100, *M* − Ph_2POH), and 314 [42, $Ph_2P(O)CH_2CHNC_4H_8O^+$].

1-(3-*Methylbut*-2-*enyl*)*piperidine Hydrochloride* (**15b**).—Sodium hydride (50% dispersion in oil; 60 mg, *ca.* 1.2 mmol) was added to a stirred solution of the alcohol (**14b**) (373 mg, 1.0 mmol) in DMF (15 ml) and stirring was continued for 2 h at 30 °C. The mixture was diluted with ether (100 ml), washed with aqueous sodium hydroxide [3 × 100 ml; 2 ml of a 30% (w/v) aqueous sodium hydroxide added to 98 ml of water for each washing] and then extracted with 0.1M hydrochloric acid (2 × 75 ml). The acid layer was made basic to pH paper with 30% (w/v) aqueous sodium hydroxide and extracted into Et_2O (3 × 75 ml). The combined organic layers were dried ($MgSO_4$) and 35% (w/v) hydrochloric acid (0.2 ml, 2 mmol) was added; evaporation under reduced pressure with azeotropic removal of traces of water with acetone followed by EtOAc, thereby gave the *amine hydrochloride* (139 mg, 72%), as needles, m.p. 193—194 °C (from EtOAc–MeOH); $\nu_{max.}$(KBr) 2 920 (CH) and 2 640 cm^{-1} (NH); δ($CDCl_3$) 5.30 (1 H, t, *J* 7.5 Hz, CH=C), 3.15 (2 H, d, *J* 7, 5 Hz, NCH_2CH), 2.66—3.05 (4 H, m, NCH_2CH_2), 1.50—1.90 (6 H, m, $NCH_2CH_2CH_2$), and 1.86 and 1.79 each (3 H, s, Me) (Found: M^+ − HCl, 153.1520. $C_{10}H_{19}N$ requires *M* − HCl, 153.1518); *m/z* 154 (38%, *M* − Cl), 153 (33, *M* − HCl), 138 (25, *M* − HCl − Me), 110 (22, *M* − HCl − C_3H_7), 98 (97, $C_5H_{10}NCH_2^+$), and 84 (100, $C_5H_{10}N^+$).

1-(2-*Cyclohexylidene-ethyl*)*piperidine Hydrochloride* (**15e**).—Similarly, the alcohol (**14e**) (411 mg, 1 mmol) and sodium hydride (50% dispersion in oil; 53 mg, *ca.* 1 mmol) in DMF (20 ml) gave the *amine hydrochloride* (190 mg, 71%) as needles, m.p. 222—223 °C (decomp.) (from Pr^iOH–hexane) (Found: C, 67.9; H, 10.35; N, 6.55. $C_{13}H_{24}ClN$ requires C, 68.0; H, 10.45; N, 6.1%); $\nu_{max.}$(Nujol) 2 500 (NH) and 1 675 cm^{-1} (C=C); δ(CD_3OD) 5.35 (1 H, t, *J* 7 Hz, CH=C), 3.72 (2 H, d, *J* 7 Hz, NCH_2CHC), 2.90—3.45 (4 H, m, NCH_2CH_2), 2.10—2.40 (4 H, m, CH_2C=CH), and 1.43—2.02 (12 H, m, $CH_2CH_2CH_2$) (Found: *M* − HCl, 193.1834. $C_{13}H_{23}N$ requires *M* − HCl, 193.1830); *m/z* 193 (14%), 192 (15, *M* − HCl − H), 98 (15, $C_5H_{10}NCH_2^+$) 85 (88, $C_5H_{10}NH^+$), and 84 (100, $C_5H_{10}N^+$).

1-(3-*Methylbut*-2-*enyl*)*pyrrolidine Hydrochloride* (**15a**).—Similarly,the alcohol (**14a**) (170 mg) and sodium hydride (50% dispersion; 25 mg) in DMF (20 ml) gave the *amine hydrochloride* (69 mg, 76%), as needles, m.p. 136.5—137.5 °C (decomp.) (from EtOAc) (Found: C, 61.7; H, 10.45; N, 7.8. $C_9H_{18}ClN$ requires C, 61.5; H, 10.25; N, 8.0%); $\nu_{max.}$(Nujol) 2 450, 2 550 (NH), and 1 670 cm^{-1} (C=C); δ(CD_3OD) 5.45 (1 H, br t, *J* 8 Hz, CH=C), 3.84 (2 H, d, *J* 8 Hz, NCH_2CH), 3.23—3.54 (4 H, m, NCH_2CH_2), 2.00—2.28 (4 H, m, NCH_2CH_2), and 1.81 and 1.85 each (3 H, s, Me) (Found: M^+ − HCl, 139.1361. $C_9H_{17}N$ requires *M* − HCl, 139.1361); *m/z* 139 (39%), 138 (48, *M* − HCl − H), 124 (67, *M* − HCl − Me), and 70 (100, $C_4H_8NCH_2^+$).

1-(2-*Cyclohexylidene-ethyl*)*pyrrolidine Hydrochloride* (**15d**).—Similarly, the alcohol (**14d**) (293 mg) and sodium hydride (50% dispersion; 37 mg) in DMF (30 ml) gave the *amine hydrochloride* (170 mg, 85%), as needles, m.p. 181—184 °C (decomp.) (from EtOAc); $\nu_{max.}$(Nujol) 2 660, 2 580 (NH), and 1 640 cm^{-1} (C=C); δ(CD_3OD) 5.28 (1 H, t, *J* 7.5 Hz, CH=C), 3.80 (2 H, d, *J* 7.5 Hz, NCH_2CH), 3.40—3.75 and 2.85—3.28 (4 H, m, NCH_2CH_2), 1.93—2.25 (8 H, m, NCH_2CH_2 and CH_2C=C), and 1.48—1.53 (6 H, br s, $CH_2CH_2CH_2$) (Found: M^+ − HCl, 179.1673. $C_{12}H_{21}N$ requires *M* − HCl, 179.1674); *m/z* 179 (24%), 178 (10, *M* − HCl − H), 71 (60, $C_4H_8NH^+$), and 70 (100, $C_4H_8N^+$).

1-(3-*Methylbut*-2-*enyl*)*morpholine Hydrochloride* (**15c**).—Similarly, the alcohol (**14c**) (325 mg) and sodium hydride (50% dispersion; 50 mg) in DMF (20 ml) gave the *amine hydrochloride* (125 mg, 90%), as needles, m.p. 185—186 °C (decomp.) (from Pr^iOH–hexane); $\nu_{max.}$(Nujol) 2 530 (NH) and 1 620 cm^{-1} (C=C); δ(CD_3OD) 5.39 (1 H, t, *J* 8 Hz, CH=C), 2.92—4.15 (10 H, m, NCH_2 and OCH_2), and 1.83 and 1.88 each (3 H, s, Me) (Found: M^+ − HCl, 155.1312. $C_9H_{17}NO$ requires *M* − HCl, 155.1311); *m/z* 155 (22%), 154 (11, *M* − HCl − H), 87 (100, $OC_4H_8NH^+$), and 86 (33, $OC_4H_8N^+$).

1-(2-*Cyclohexylidene-ethyl*)*morpholine Hydrochloride* (**15f**).—Similarly, the alcohol (**14f**) (270 mg) and sodium hydride (50% dispersion; 37 mg) in DMF (25 ml) gave the amine hydrochloride (149 mg, 81%), as needles, m.p. 208—209 °C (from Pr^iOH) (lit.,[2] 208—209 °C); $\nu_{max.}$(Nujol) 2 500 and 2 460 cm^{-1} (NH); δ(CD_3OD) 5.36 (1 H, t, *J* 8 Hz, CH=C), 3.78—4.10 (4 H, m, CH_2O), 3.82 (2 H, d, *J* 8 Hz, NCH_2CH), 3.15—3.50 (4 H, m, NCH_2CH_2), 1.16—1.48 (4 H, m, CH_2C=CH), and 1.65 (6 H, br s, $CH_2CH_2CH_2$) (Found: M^+ − HCl, 195.1616. $C_{12}H_{21}NO$

requires M − HCl, 195.1623); m/z 195 (10%), 100 (100, $OC_4H_8NCH_2^+$), 87 (89, $OC_4H_8NH^+$), and 86 (50, $OC_4H_8N^+$).

(Z)-1-(*But-2-enyl*)*piperidine Hydrochloride Z*-(**17a**).—Similarly, the alcohol *erythro*-(**16a**) (199 mg) and sodium hydride (50% dispersion; 30 mg) gave the *amine hydrochloride* (75 mg, 81%), as needles, m.p. 176—178 °C (from EtOAc–Pr^{i}OH); $\nu_{max.}$(Nujol) 2 500 (NH), 1 660 (C=C), and 715 cm^{-1} (HC=CH bending); δ(CD_3OD) 6.11 (1 H, dq, J 11, 7 Hz, MeC*H*), 5.60 (1 H, m, C*H*CH_2), 3.80 (2 H, d, J 7 Hz, NCH_2CH), 2.85—3.50 (4 H, m, NCH_2CH_2), 1.54—2.04 (6 H, m, $NCH_2CH_2CH_2$), and 1.78 (d, J Hz, Me) (Found: M^+ − Cl, 140.1430. $C_9H_{18}N$ requires M − Cl 140.1439); m/z 140 (1%, M − Cl), 139 (39, M − HCl − H), 98 (84, $CH_2N^+C_5H_{10}$), 85 (10, $C_5H_{10}NH^+$), 84 (100, $C_5H_{10}N^+$), and 55 (82, $C_4H_7^+$).

(E)-1-(*But-2-enyl*)*piperidine Hydrochloride E*-(**17a**).—Similarly, the alcohol *threo*-(**16a**) (198 mg) and sodium hydride (50% dispersion; 30 mg) in DMF (20 ml) gave the *amine hydrochloride* (72 mg, 74%), as needles, m.p. 150—151 °C (decomp.) (from EtOAc); $\nu_{max.}$(Nujol) 2 500 and 2 480 (NH), 1 680 (C=C), and 965 cm^{-1} (HC=CH out of plane deformation); δ(CD_3OD) 6.06 (1 H, dq, J 15, 7 Hz, MeC*H*), 5.55 (1 H, dt, J 15, 7 Hz, NCH_2CH), 3.62 (2 H, d, J 7 Hz, NCH_2CH), 2.85—3.59 (4 H, m, NCH_2CH_2), 1.50—2.00 (6 H, m, $NCH_2CH_2CH_2$) and 1.76 (3 H, d, J 7 Hz, Me), (Found: M^+ − Cl, 140.1429. $C_9H_{18}N$ requires M − Cl, 140.1439); m/z 140 (3%), 139 (40, M − HCl), 124 (34, M − HCl − Me), 85 (100, $C_5H_{10}NH^+$), and 55 (87, M − $C_5H_{10}NH$).

(Z)-1-(3-*Phenylallyl*)*piperidine Hydrochloride Z*-(**17b**).—Similarly, the alcohol *erythro*-(**16b**) (140 mg) and sodium hydride (50% dispersion; 20 mg) in DMF (20 ml) gave the *amine hydrochloride* (65 mg, 72%), as needles, m.p. 154—156 °C (decomp.) (from EtOAc–Pr^{i}OH); $\nu_{max.}$(Nujol) 2 920 (CH), 2 500 (NH), and 1 590 cm^{-1} (C=C); δ(CD_3OD) 7.15—7.48 (5 H, m, Ph), 6.96 (1 H, dt, J 11, 2 Hz, C*H* Ph), 5.84 (1 H, dt, J 11, 7 Hz, NCH_2CH), 3.96 (1 H, dd, J 7, 2 Hz, NCH_2CH), 3.05—3.35 (4 H, m, NCH_2CH_2), and 1.55—1.95 (6 H, m, $NCH_2CH_2CH_2$) (Found: M^+ − HCl, 201.1531. $C_{14}H_{19}N$ requires M − HCl, 201.1517); m/z 201 (34%), 200 (20, M − HCl − H), 117 (53, $PhC_3H_4^+$), and 110 (100, $C_7H_{12}N^+$).

(E)-1-(3-*Phenylallyl*)*piperidine Hydrochloride E*-(**17b**).—Similarly, the alcohol *threo*-(**16b**) (250 mg) and sodium hydride (50% dispersion; 30 mg) in DMF (30 ml) gave the *amine hydrochloride* (140 mg, 86%) as needles, m.p. 210—211 °C (decomp.) (from EtOAc–Pr^{i}OH), $\nu_{max.}$(Nujol) 2 920 (CH), 2 500 (NH), 1 590 (C=C), and 960 cm^{-1} (HC=CH out-of-plane deformation); δ(CD_3OD) 7.23—7.57 (5 H, m, Ph), 6.89 (1 H, d, J 16 Hz, C*H*Ph), 6.36 (1 H, dt, J 16, 8 Hz, C*H*CHPh), 3.86 (2 H, d, J 8 Hz, NCH_2CH), 3.05—3.55 (4 H, m, NCH_2CH_2), and 1.50—2.10 (6 H, m, $NCH_2CH_2CH_2$) (Found: M^+ − HCl, 201.1531. $C_{14}H_{19}N$ requires M − HCl, 201.1517); m/z 201 (35%), 200 (30, M − HCl − H), 117 (53, $PhC_3H_4^+$), and 110 (100, $C_7H_{12}N^+$).

(Z)-1-(3,4-*Dimethylpent-2-enyl*)*piperidine Hydrochloride Z*-(**22**).—Similarly, the alcohol *erythro*-(**21**) (150 mg) and sodium hydride (50% dispersion; 25 mg) in DMF (20 ml) gave the *amine hydrochloride* (76 mg, 86%) as needles, m.p. 188—190 °C (decomp.) from (EtOAc); $\nu_{max.}$(Nujol) 2 900 (CH), 2 480 (NH) and 1 575 cm^{-1} (C=C); δ(CD_3OD) 5.29 (1 H, t, J 7.5 Hz, C*H*=C), 3.74 (2 H, d, J 7.5 Hz, NCH_2CH), 3.05—3.37 (4 H, m, NCH_2CH_2), 2.89 (1 H, septet, J 7 Hz, Me_2CH), 1.52—2.03 (6 H, m, $NCH_2CH_2CH_2$), 1.78 (3 H, s, *Me*C=CH), and 1.00 (6 H, d, J 7 Hz, Me_2CH) (Found: M^+ − HCl, 181.1840. $C_{12}H_{23}N$ requires M − HCl, 181.1830); m/z 182 (0.5%, M − Cl), 181 (4, M − OHCl), 180 (3, M − HCl − H), 165 (4, M − HCl − Me), 86 (61, $C_5H_{10}NH_2^+$), and 84 (100, $C_5H_{10}N^+$).

(E)-1-(3,4-*Dimethylpent-2-enyl*)*piperidine Hydrochloride E*-(**22**).—Similarly, the alcohol *threo*-(**21**) (150 mg) and sodium hydride (50% dispersion; 20 mg) in DMF (20 ml) gave the *amine hydrochloride* (80 mg, 91%) as needles, m.p. 193—194 °C (decomp.) (from EtOAc–Pr^{i}OH) (Found: C, 63.9; H, 10.75; N, 6.3. $C_{12}H_{24}ClN{\cdot}H_2O$ requires C, 63.5; H, 11.05; N, 6.2%); $\nu_{max.}$(Nujol) 2 900 (CH), 2 480 (NH), 1 655 (C=C), and 840 cm^{-1} (RCH=CHR out-of-plane deformation); δ(CD_3OD) 5.40 (1 H, t, J 7.5 Hz, CH=C), 3.71 (2 H, d, J 7.5 Hz, NCH_2CH), 3.05—3.77 (4 H, m, NCH_2CH_2), 2.37 (1 H, distorted septet, J 7 Hz, Me_2CH), 1.50—2.03 (6 H, m, $NCH_2CH_2CH_2$), 1.73 (3 H, s, *Me*C=CH), and 1.03 (6 H, d, J 7 Hz, Me_2CH) (Found: M^+ − HCl, 181.1838. $C_{12}H_{23}N$ requires M − HCl, 181.1831), m/z 181 (13), 180 (11, M − HCl − H), 166 (11, M − HCl − Me), 138 (58, M − HCl − C_3H_7), 85 (83, $C_5H_{10}NH^+$), and 84 (100, $C_5H_{10}N^+$).

(Z)-1-(3-*Methylhex*-2-*enyl*)*pyrrolidine Hydrochloride Z*-(**20**).—Similarly, the alcohol *erythro*-(**19**) (142 mg) and sodium hydride (50% dispersion; 25 mg) in DMF (20 ml) gave the *amine hydrochloride* (65 mg, 88%) as needles, m.p. 142—314 °C (decomp.) (from EtOAc); $\nu_{max.}$(Nujol) 2 950 (CH), 2 480, 2 570 (NH), and 1 675 cm^{-1} (C=C); δ(CD_3OD) 5.40 (1 H, t, J 7 Hz, CH=C), 3.82 (2 H, d, J 7 Hz, NCH_2CH), 3.21—3.47 (4 H, m, NC*H*CH_2), 1.95—2.28 (6 H, m, NCH_2CH_2 and $MeCH_2CH_2$), 1.83 (3 H, s, Me), 1.46 (2 H, sextet, J 7 Hz, MeCH_2), and 0.93 (3 H, t, J 7 Hz, *Me*CH_2) (Found: M^+ − HCl, 167.1673. $C_{11}H_{21}N$ requires M − HCl, 167.1673); m/z 168 (2%, M − Cl), 167 (23), 166 (20, M − HCl − H), 124 (25, M − HCl − C_3H_7), 84 (48, $C_4H_8N^+CH_2$), 71 (72, $C_4H_8NH^+$), and 70 (100, $C_4H_8N^+$).

(E)-1-(3-*Methylhex*-2-*enyl*)*pyrrolidine Hydrochloride E*-(**20**).—Similarly, the alcohol *threo*-(**19**) (515 mg) and sodium hydride (50% dispersion; 75 mg) in DMF (50 ml) gave the *amine hydrochloride* (238 mg, 87%) as needles, m.p. 145—147 °C (decomp.) (from EtOAc); $\nu_{max.}$(Nujol) 2 950 (CH), 2 470, 2 570 (NH), and 1 670 cm^{-1} (C=C); δ(CD_3OD) 5.46 (1 H, t, J 7.5 Hz, CH=C), 3.89 (2 H, d, J 7 Hz, NCH_2CH), 3.18—3.55 (4 H, m, NCH_2CH_2), 1.93—2.28 (4 H, m, NCH_2CH_2), 2.08 (2 H, t, J 7.5 Hz, $MeCH_2CH_2$), 1.78 (3 H, s, Me), 1.48 (2 H, br septet, J 7.5 Hz, MeCH_2), and 0.86 (3 H, t, J 7.5 Hz, *Me*CH_2) (Found: M^+ − HCl, 167.1679. $C_{11}H_{21}N$ requires M − HCl, 167.1674); m/z 167 (34, M − HCl), 166 (28, M − HCl − H), 138 (29, M − HCl − Et), 124 (38, M − HCl − Pr), 84 (48, $C_4H_8N^+CH_2$), 71 (79, $C_4H_8NH^+$), and 70 (100, $C_4H_8N^+$).

(Z)-1-(*But-2-enyl*)*morpholine Hydrochloride Z*-(**17c**).—Similarly, the alcohol *erythro*-(**16c**) (1.077 g) and sodium hydride (50% dispersion; 170 mg) in DMF (70 ml) gave the *amine hydrochloride* (600 mg, 84%), as needles, m.p. 150—151 °C (from EtOAc) (Found: C, 54.2; H, 8.95; N, 7.7. $C_8H_{16}ClNO$ requires C, 54.1; H, 9.0; N, 7.8%); $\nu_{max.}$(Nujol) 2 450 (NH), 1 660 (C=C) and 720 cm^{-1} (HC=CH out-of-plane deformation); δ(CD_3OD) 6.13 (1 H, dq, J 11, 7 Hz, MeC*H*), 5.65 (1 H, distorted dt, J 11, 8 Hz, NCH_2CH), 3.65—4.05 (6 H, m, OCH_2 and NCH_2CH), 3.20—3.48 (4 H, m, NCH_2CH_2), and 1.80 (3 H, d, J 7 Hz, *Me*CH) [Irradiation at 1.80 gives 6.13 (1 H, d, J 11 Hz, MeC*H*) and 5.65 (1 H, dt, J 11, 8 Hz, NCH_2CH)] (Found: M^+ − HCl, 141.1154. $C_8H_{15}NO$ requires M − HCl, 141.1154); m/z 141 (22, M − HCl), 100 (23, $OC_4H_8N^+CH_2$), 87 (100, $OC_4H_8NH^+$), and 55 (80, $C_4H_7^+$).

(E)-1-*But-2-enylmorpholine Hydrochloride E*-(**17c**).—Similarly, the alcohol *threo*-(**16c**) (1.077 g) and sodium hydride (50%

dispersion; 170 mg) in DMF (70 ml) gave the *amine hydrochloride* (612 mg, 86%), as needles, m.p. 202—203 °C (from EtOAc) (Found: C, 54.1; H, 9.2; N, 7.9. $C_8H_{16}ClNO$ requires C, 54.1; H, 9.0; N, 7.8%); $\nu_{max.}$(Nujol) 2 450 (NH), 1 670 (C=C), and 960 cm^{-1} (HC=CH out-of-plane deformation); δ(CD_3OD) 6.10 (1 H, dq, *J* 16.5, 7 Hz, MeC*H*), 5.61 (1 H, dt, *J* 16.5, 7 Hz, NCH_2CH), 3.80—4.03 (4 H, t, *J* 5 Hz, CH_2O), 3.70 (2 H, d, *J* 7 Hz, NCH_2CH), 3.15—3.40 (4 H, m, NCH_2CH_2), and 1.78 (3 H, d, *J* 7 Hz, *Me*CH) (Found: M^+ − HCl, 141.1153. $C_8H_{15}NO$ requires *M* − HCl, 141.1153); *m/z* 141 (18, *M* − HCl), 100 (13, $OC_4H_8N^+CH_2$), 87 (78, $OC_4H_8NH^+$), and 55 (100, $C_4H_7^+$).

(Z)-1-(3-*Phenylallyl*)*morpholine Hydrochloride Z*-(**17d**).—To a solution of the dimethyl-t-butylsilyl ether of alcohol *erythro*-(**16d**) (290 mg, 0.542 mmol) in THF (25 ml) was added tetrabutylammonium fluoride (1M solution in THF; 11 ml, 11 mmol) at 25 °C and the mixture stirred for 1 h. The mixture was diluted with water (100 ml) and extracted with CH_2Cl_2 (2 × 50 ml). The combined extracts were dried ($MgSO_4$) and evaporated under reduced pressure to give the alcohol *erythro*-(**16d**) as an impure orange gum; this was dissolved in DMF (8 ml) and sodium hydride (50% dispersion; 33 mg) was added to it. The mixture was stirred at 25 °C for 2 h after which it was worked up to give the *amine hydrochloride* (88 mg, 68% overall), as needles, m.p. 173—174 °C (from EtOAc–Pr^{i}OH) (Found: C, 65.0; H, 7.85; N, 5.5. $C_{13}H_{18}ClNO$ requires C, 65.1; H, 7.55; N, 5.8%); $\nu_{max.}$(Nujol) 2 425, 2 525 (NH), and 670 cm^{-1} (HC=CH out-of-plane deformation); δ(CD_3OD) 7.21—7.56 (5 H, m, Ph), 7.01 (1 H, dt, *J* 12, 2 Hz, PhC*H*), 5.91 (1 H, dt, *J* 12, 6.5 Hz, NCH_2CH), 4.10 (2 H, dd, *J* 6.5, 2 Hz, NCH_2CH), 3.80—3.94 (4 H, m, CH_2O), and 2.90—3.50 (4 H, m, NCH_2); *m/z* 203 (50, *M* − HCl), 202 (20, *M* − HCl − H), 117 (100, $PhC_3H_4^+$), and 112 (93, $C_6H_{10}NO^+$).

Wittig–Horner Completion using 1,5-*Diazabicyclo*[4.3.0]*non*-5-*ene* (DBN): 1-(2-*Cyclohexylidene-ethyl*)*piperidine Hydrochloride* (**15e**).—A solution of the alcohol (**14e**) (395 mg, 0.96 mmol) and DBN (120 mg, 0.97 mmol) in CH_2Cl_2 (5 ml) was heated under reflux for 60 h and then concentrated at atmospheric pressure to 1 ml. The mixture was separated by p.l.c. (acetone) and the acetone extract from the band at R_F 0.3—0.5 acidified with 0.2 ml HCl (35% in water); it was then evaporated under reduced pressure, and traces of water azeotroped with acetone and EtOAc to give the amine hydrochloride (**8e**) (157 mg, 70%) as needles, m.p. 221—222 °C (decomp.) (from EtOAc) (see above).

1-(2-*Cyclohexylidene-ethyl*)*pyrrolidine Hydrochloride* (**15d**).—In a similar manner, the alcohol (**14d**) (380 mg, 0.96 mmol) and DBN (120 mg, 0.97 mmol) in CH_2Cl_2 (5 ml) gave the amine hydrochloride (**8d**) (167 mg, 80%) (see above).

Wittig–Horner Completion by Pyrolysis: (Z)-1-(3,4-*Dimethylpent*-2-*enyl*)*piperidine Z*-(**22**).—The alcohol *erythro*-(**21**) (100 mg) was heated in a Kugelrohr oven under reduced pressure (0.023 mmHg) to an oven temperature of 170 °C. The free amine of *Z*-(**22**) (35 mg, 75%) was collected in an ice-cooled bulb outside the oven, as a liquid; δ(CCl_4) 5.13 (1 H, t, *J* 7 Hz, CH_2CH), 2.88 (2 H, distorted d, *J* 7 Hz, NCH_2CH), 2.66—2.85 (1 H, m, Me_2CH), 2.20—2.41 (4 H, m, NCH_2CH_2), 1.27—1.65 (6 H, m, $NCH_2CH_2CH_2$), 1.56 (3 H, distorted s, *Me*C=CH), and 0.91 (6 H, d, *J* 7 Hz, Me_2CH).

(E)-1-(3,4-*Dimethylpent*-2-*enyl*)*piperidine E*-(**22**).—Similarly, the alcohol *threo*-(**21**) (100 mg) gave the free amine of *E*-(**22**) as a liquid (31 mg, 70%); δ(CCl_4) 5.13 (1 H, t, *J* 7 Hz, CH=C), 2.82 (2 H, d, *J* 7 Hz, CH_2CH=C) 2.10—2.45 (5 H, m, NCH_2CH_2 and Me_2CH), 1.26—1.67 (6 H, m, $NCH_2CH_2CH_2$), 1.57 (3 H, s, *Me*C=CH), and 1.01 96 H, d, *J* 7 Hz, Me_2CH).

β-*Amino*-β′-*hydroxyalkylphosphine Oxides:* 3-*Benzamido*-2-*diphenylphosphinoyl*-3-*methyl*-1-*phenylbutan*-1-*ol* (**31c**).—BuLi (4.02 ml, 6 mmol) was added dropwise to a stirred solution of the amide (**25**) (1.13 g, 3 mmol) in LiBr-saturated THF (30 ml) at −20 °C and stirring continued for 1 h, thereby forming a deep orange-red solution of the dianion. The flask was cooled to −78 °C, and benzaldehyde (0.31 ml, 3 mmol) was added dropwise. After being stirred for a further 30 mins the now colourless solution was quenched with saturated aqueous ammonium chloride and allowed to warm to room temperature; it was then extracted with CH_2Cl_2 (3 × 75 ml), and the extract dried ($MgSO_4$), and evaporated under reduced pressure to give a colourless oil. Flash chromatography[22] (EtOAc–Et_3N, 97:3), of this followed by h.p.l.c. (EtOAc–Et_3N, 97:3) gave the alcohol *threo*-(**31c**) (1.01 g, 80%), as a colourless gum, R_F (Et_2O) 0.10; $\nu_{max.}$($CDCl_3$) 3 430, 3 300 (OH, NH), 1 650 (C=O I), 1 510 (C=O II), 1 435 (P–Ph), and 1 195 cm^{-1} (P=O); δ($CDCl_3$) 6.75—7.80 (20 H, m, Ph), 6.40 (1 H, br s, NH), 6.03 (1 H, s, OH), 5.55 (1 H, d, J_{PH} 26 Hz, C*H*OH), 4.50 (1 H, d, J_{PH} 9 Hz, PCH), 1.86 (3 H, s, *Me*, and 1.70 (3 H, s, *Me*); *m/z* 377 (38%, *M* − PhCHO), 321 [30, $Ph_2P(O)CH_2CH(OH)Ph^+$], 257 [100, $Ph_2P(O)CH_2CMe_2^+$], 215 [80, $Ph_2P(O)CH_2^+$], and 201 (69, Ph_2PO^+).

4-*Benzamido*-3-*diphenylphosphinoyl*-4-*methylpentan*-2-*ol* (**31a**).—In a similar way, the amide (**25**) (1.13 g, 3 mmol) and BuLi (4.02 ml, 6 mmol) in LiBr-saturated THF (30 ml) and acetaldehyde (0.25 ml) gave the *alcohol* (0.91 g, 72%) as a mixture of diastereoisomers, as microcrystalline prisms, m.p. 140—206 °C (decomp.) (from EtOAc) (Found: C, 71.1; H, 6.6; H, 3.3. $C_{25}H_{28}NO_3P$ requires C, 71.3; H, 6.65; N, 3.3%); R_F (EtOAc–Et_3N, 97:3) 0.29; $\nu_{max.}$($CDCl_3$) 3 440, 3 350 (OH, NH), 1 650 (C=O I), 1 510 (C=O II), 1 440 (P–Ph), and 1 160 cm^{-1} (P=O); δ($CDCl_3$) 6.95—8.10 (15 H, m, Ph_2PO and Ph), 6.20 (minor diastereoisomer, 1 H, s, NH), 6.05 (major diastereoisomer, 1 H, s, NH), 4.30—4.80 (both diastereoisomers, 1 H, m, CHOH), 4.38 (both diastereoisomers, 1 H, s, OH), 4.04 (both diastereoisomers, 1 H, dd, J_{PH} 8, J_{HH} 2 Hz, PCH), 1.73 (minor diastereoisomer, 6 H, s, Me_2C), 1.66 (major diastereoisomer, 6 H, s, Me_2C), 1.45 (minor diastereoisomer, 3 H, d, *J* 7 Hz, *Me*CH), and 1.10 (major diastereoisomer, 3 H, d, *J* 7 Hz, *Me*CH) (Ratio of diastereoisomers judged from n.m.r. to be 30:70. From the results of the elimination reaction, the major isomer is the *threo* form.) (Found: M^+, 421.1807. $C_{25}H_{28}NO_3P$ requires *M*, 421.1807), *m/z* 421 (0.32%), 377 (22%, *M* − MeCHO), 260 [95, $Ph_2P(O)CH_2CH(OH)CH_2^+$], 245 [100, $Ph_2P(OH)C_3H_7^+$], and 201 (60, Ph_2PO^+).

5-*Benzamido*-4-*diphenylphosphinoyl*-2,5-*dimethylheptan*-3-*ol* (**31b**).—Similarly, the amide (**24**) (754 mg, 2 mmol) and BuLi (2.70 ml) in LiBr-saturated THF (50 ml) with isobutyraldehyde (0.3 ml) gave, upon work-up, a colourless oil which was separated by p.l.c. (Et_2O, triple elution) to afford the *alcohol erythro*-(**31b**) (117 mg, 13%) as prisms, m.p. 145—146.5 °C (decomp.) (from CH_2Cl_2–hexane), R_F (Et_2O) 0.20; $\nu_{max.}$($CDCl_3$) 3 420 (NH, OH), 2 950 (CH), 1 655 (C=O I), 1 515 (C=O II), 1 440 (P–Ph), and 1 170 cm^{-1} (P=O); δ($CDCl_3$) 6.90—8.07 (15 H, m, Ph), 5.63 (1 H, s, NH), 4.46 (1 H, d, *J* 9 Hz, PCH), 4.06 (1 H, d, *J* 2.5 Hz, OH), 3.62—3.95 (1 H, m, C*H*OH), 1.95—2.43 (1 H, m, Me_2CH), 1.83 (3 H, s, Me), 1.76 (3 H, s, Me), 0.98 (3 H, d, *J* 7 Hz, *Me*CH), and 0.90 (3 H, d, *J* 7 Hz, *Me*CH) (Found: M^+, 449.2103. $C_{27}H_{32}NO_3P$ requires *M*, 449.2120); *m/z* 450 (0.2%, MH^+), 449 (0.2, M^+), 406 (13, *M* − Pr), 377 (19, *M* − C_3H_7CHO), 285 (30, *M* − Pr − PhCO), 245 [100, $Ph_2P(O)CH_2CHO^+$], and 201 (27, Ph_2PO^+); and the *alcohol threo*-(**31b**) (413 mg, 47%), as prisms, m.p. 169—172 °C (decomp.)

(from CH_2Cl_2–hexane) (Found: C, 71.7; H, 7.3; N, 3.2. $C_{27}H_{32}NO_3P$ requires C, 72.1; H, 7.15; N, 3.1%); R_F (Et_2O) 0.10; $\nu_{max.}$($CDCl_3$) 3 420, 3 300 (NH, OH), 2 950 (CH), 1 655 (C=O I), 1 515 (C=O II), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.13—8.21 (15 H, m, Ph), 6.52 (1 H, s, NH), 5.10 (1 H, br s, OH), 4.16 (1 H, d, *J* 10.5 Hz, PCH), 3.74 (1 H, dd, J_{PH} 20, J_{HH} 9 Hz, C*H*OH), 1.68 (6 H, s, Me_2C), 1.21—1.54 (1 H, m, Me_2CH), 0.83 (3 H, d, *J* 6 Hz, *Me*CH), and 0.66 (3 H, d, *J* 6 Hz, *Me*CH); *m/z* 406 (8%, *M* − Pr) and 285 (25, *M* − C_3H_7CHO − PhCO), 245 [100, $Ph_2P(O)CH_2CHO^+$], and (22, Ph_2PO^+).

4-*Benzamido*-3-*diphenylphosphinoyl*-2-*methylpentan*-1-*ol* (**27a**).—In a similar manner the amide [15] (**23**) (363 mg, 1 mmol) BuLi (1.35 ml) in LiBr-saturated THF (30 ml), and acetone (0.1 ml) gave, after p.l.c. (EtOAc–Et_3N, 97:3) followed by h.p.l.c. (EtOAc–Et_3N, 97:3), the alcohol (273 mg, 65%) as microcrystalline prisms, m.p. 117—119 °C (decomp.) (from EtOAc) (Found: C, 71.3; H, 6.7; N, 3.4. $C_{25}H_{28}NO_3P$ requires C, 71.3; H, 6.65; N, 3.4%); R_F (EtOAc–Et_3N, 97:3) 0.40; $\nu_{max.}$(Nujol) 3 400, 3 300 (OH, NH), 2 950 (CH), 1 640 (C=O I), 1 520 (C=O II), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ($CDCl_3$) 7.20—8.07 (16 H, m, Ph_2PO, Ph, and NH), 5.27 (1 H, br s, OH), 4.50 (1 H, ddq, J_{PH} 29, J_{HMe} 7 Hz, J_{HH} 2 Hz, PCHC*H*Me), 2.98 (1 H, dd, J_{PH} 11, J_{HH} 2 Hz, PCH), 1.59 (3 H, d, *J* 7 Hz, *Me*CH), 1.56 (3 H, s, *Me*COH), and 1.29 (3 H, s, MeCOH); *m/z* 406 (3%, *M* − Me), 363 (26, *M* − Me_2CO), 259 [24, $Ph_2P(O)CH_2CHMeNH_2^+$], 202 (55, Ph_2POH^+), and 105 (100, $PhCO^+$).

1-(2-*Benzamido*-1-*diphenylphosphinoylpropyl*)*cyclohexanol* (**27b**).—Similarly, the amide (**25**) (363 mg, 1 mmol) and BuLi (1.35 ml) in LiBr-saturated THF (30 ml), with cyclohexanone (0.1 ml) gave, after p.l.c. (EtOAc–Et_3N, 97:3) and h.p.l.c. (EtOAc–Et_3N, 97:3), the *alcohol* (280 mg, 61%), as prisms, m.p. 113—115 °C (decomp.) (from EtOAc) (Found: C, 72.8; H, 7.3; N, 2.7. $C_{28}H_{32}NO_3P$ requires C, 72.9; H, 6.95; N, 3.0%); R_F(EtOAc–Et_3N, 97:3) 0.43; $\nu_{max.}$($CDCl_3$) 3 430, 3 320 (NH, OH), 1 650 (C=O I), 1 515 (C=O II), 1 435 (P–Ph), and 1 160 cm^{-1} (P=O); δ($CDCl_3$) 7.20—8.05 (16 H, m, Ph and NH), 4.70 (1 H, s, OH), 4.45 (1 H, ddq, J_{PH} 28, J_{HME} 7, J_{HH} 2 Hz, PCHC*H*Me), 2.98 (1 H, dd, J_{PH} 10, J_{HH} 2 Hz, PCH), 1.05—2.18 (10 H, m, CH_2), and 1.767 (3 H, d, *J* 7 Hz, Me) (Found: M^+, 461.2131. $C_{28}H_{32}NO_3P$ requires *M*, 461.2120); *m/z* 461 (10%), 363 (21, *M* − $C_5H_{10}CO$), 314 (38), C, 296 [80, $Ph_2P(O)C_7H_{11}^+$], 243 [75, $Ph_2P(O)C_3H_6^+$], and 201 (100, Ph_2PO^+).

4-*Benzamido*-3-*diphenylphosphinoylpentan*-2-*ol* (**29**).—Similarly, the amide (**25**) (1.009 g, 3 mmol), BuLi (6.02 ml, 7 mmol) in LiBr-saturated THF (60 ml) with acetaldehyde (0.25 ml) gave, after h.p.l.c. (EtOAc–Et_3N, 97:3), the *alcohol threo*-(**29**) (381 mg, 31.2%), as microcrystalline prisms, m.p. 176—717 °C (decomp.) (from EtOAc) (Found: C, 70.7; H, 6.6; N, 3.5. $C_{24}H_{26}NO_3P$ requires C, 70.8; H, 6.4; N, 3.4%); R_F (EtOAc–Et_3N, 97:3) 0.33; $\nu_{max.}$ 3 350 (OH, NH), 1 645 (C=O I), 1 520 (C=O II), 1 440 (P–Ph), and 1 160 cm^{-1} (P=O); δ($CDCl_3$) 8.53 (1 H, d, *J* 7 Hz NH), 7.15—8.10 (15 H, m, Ph), 4.10—4.81 (3 H, m, C*H*OH, CHN), 2.60 (1 H, dt, J_{PH} 10, J_{HH} 3.5 Hz, PCH), and 1.27 and 1.33, both (3 H, d, *J* 7 Hz, Me); *m/z* 408 (13%, MH^+), 363 (40, *M* − MeCHO), 260 [50, $Ph_2P(O)CH_2CH(OH_2)CH_3^+$], 243 [100, $Ph_2P(O)CH_2CHCH_2^+$], 206 (79, *M* − Ph_2PO), 202 (69, Ph_2POH^+), and 201 (55, Ph_2PO^+); and the alcohol erythro-(**29**) (445 mg, 36.5%) as small prisms, m.p. 217—219 °C (from EtOAc–MeOH), R_F(EtOAc–Et_3N, 97:3) 0.28; $\nu_{max.}$($CDCl_3$) 3 350 (NH, OH), 1 645 (C=O I), 1 520 (C=O II), 1 440 (P–Ph), and 1 160 cm^{-1} (P=O); δ($CDCl_3$) 7.08—8.00 (16 H, m, Ph and NH), 4.44—4.87 (2 H, m, C*H*OH, CHN), 3.95 (1 H, br s, OH), 2.76 (1 H, dt, J_{PH} 10, J_{HH} = J_{HH} 2.5 Hz, PC*H*), and 1.47 and 1.58 each (3 H, d, *J* 7 Hz, Me) (Found: M^+, 407.1646. $C_{24}H_{26}NO_3P$ requires *M*, 407.1650), *m/z* 407 (0.4%), 363 (34, *M* − MeCHO), 243 (30, $Ph_2PO{\cdot}C_3H_6^+$), 201 (25, Ph_2PO^+), and 105 (100, $PhCO^+$).

Allyl Amides: (E)-N-(2-*Methyl*-4-*phenylbut*-3-*en*-2-*yl*)*benzamide E*-(**32c**).—A mixture of the alcohol *threo*-(**31c**) (0.95 g, 1.97 mmol) and sodium hydride (50% dispersion; 103 mg, 2.06 mmol) in DMF (70 ml) was stirred at room temperature for 2 h. Ether (200 ml) was added and the ether layer was washed with water (3 × 200 ml), dried ($MgSO_4$), and evaporated under reduced pressure to give the *allyl amide* (0.44 g, 84%), as needles, m.p. 152—153 °C (from EtAOc), R_F(Et_2O)0.89; $\nu_{max.}$(Nujol) 3 310 (NH), 2 950 (CH), 1 640 (C=O I), 1 540 (C=O II), and 940 cm^{-1} (HC=CH out of plane def.); δ($CDCl_3$) 7.25—7.87 (5 H, m, Ph), 6.55 (2 H, s, HC=CH), 6.20 (1 H, br s, NH), and 1.67 (6 H, s, Me) (Found: M^+, 265.1459. $C_{18}H_{19}NO$ requires *M*, 265.1467), *m/z* 265 (15%), 105 (90, $PhCO^+$), 77 (30, Ph^+), and 57 (100, Me_2CNH^+).

Praseodymium Shift Experiment to Establish the Geometry of the Double Bond in E-(**28c**).—Adding [$^2H_9$]-tris (6,6,7,7,8,8,8-heptafluoro-2,2-dimethyloctane-3,5-dionato)praseodymium {[$^2H_9$]-Pr(fod)$_3$} (*M*, 1 033.44) to the amide *E*-(**30c**) (24 mg) in $CDCl_3$ and measuring the spectra at total concentrations of 2.0, 6.7, 14.1, and 25.6 mol % gave straight-line graphs of mol % *vs.* shift (p.p.m.) which gave the following praseodymium-induced-shifts (P.I.S.):

Peak	P.I.S. (p.p.m.)
NH	−7.13
CH_3	−5.34
CH_A (vinyl)	−5.15
CH_B (vinyl)	−6.75

From the 14.1 and 25.6 mol % spectra, the geminal coupling constant was measured as 16 Hz, and the geometry of the double bond assigned *E*; the i.r. spectrum ($\nu_{max.}$ 940 cm^{-1}) confirmed this evidence.

In view of the relative similarity of the P.I.S. values for all four peaks, especially that for the amide proton, it is likely that the shift reagent is co-ordinated to the amide oxygen rather than nitrogen. No firm assignment of the absolute positions of CH_A and CH_B could be made.

N-(2-*Methylpent*-3-*en*-2-*yl*)*benzamide* (**32a**).—Similarly, the alcohol mixture (**31a**) (320 mg) and sodium hydride (50% dispersion; 50 mg) in DMF (20 ml) gave the amide mixture (138 mg, 86%) as needles, m.p. 88—91 °C [from Et_2O–light petroleum (b.p. 60—80 °C)] (Found: C, 77.05; H, 8.45; N, 6.7. $C_{13}H_{17}NO$ requires C, 76.85; H, 8.35; N, 6.9%), R_F (Et_2O–hexane, 50:50) 0.312 (minor), 0.395 (major). N.m.r. showed the product to be 75:mixture of isomers, the major one of which was isolated by h.p.l.c. (Et_2O–hexane, 40:60) on a small scale, as needles, m.p. 95—96.5 °C [from Et_2O–light petroleum (b.p. 60—80 °C], R_F (Et_2O–hexane, 50:50) 0.40; $\nu_{max.}$($CDCl_3$) 3 430 (NH I), 3 300 (NH II), 1 660 (C=O I), 1 500 (C=O II), and 960 cm^{-1} (HC=CH out-of-plane deformation); δ($CDCl_3$) 7.25—7.48 and 7.63—7.83 (5 H, m, Ph), 6.12 (1 H, br s, NH), 5.80 (1 H, d, *J* 15 Hz, MeCH=C*H*), 5.37—5.67 (1 H, m, MeC*H*), 1.64 (3 H, d, *J* 5 Hz, *Me*CH), and 1.47 (6 H, s, Me_2C) (Found: M^+, 203.1299. $C_{13}H_{17}NO$ requires *M*, 203.1310); *m/z* 203 (25%), 188 (18, *M* − Me), 105 (100, $PhCO^+$), and 77 (48, Ph^+).

(Z)-N-(2,5-*Dimethylhex*-3-*en*-2-*yl*)*benzamide Z*-(**32b**).—Similarly the alcohol *erythro*-(**29b**) (78 mg) and sodium hydride (50% dispersion; 10 mg) in DMF (10 ml) gave the *amide* (33 mg, 82%), as needles, m.p. 114—115 °C [from light petroleum (b.p. 40—60 °C)], R_F (Et_2O) 0.68; $\nu_{max.}$(Nujol) 3 320 (NH), 1 630

(C=O I), and 1 530 cm^{-1} (C=O II); $\delta(CDCl_3)$ 7.27—7.58 and 7.68—7.86 (5 H, m, Ph), 6.21 (1 H, br s, NH), 5.53 (1 H, d, *J* 12 Hz, NCC*H*=CH), 5.16 (1 H, dd, *J* 10, 12 Hz, CH=C*H*CH), 2.70—3.10 (1 H, m, Me_2CH), 1.59 (6 H, s, Me_2C), and 0.94 (6 H, d, *J* 7 Hz, Me_2CH) (Found: M^+, 231.1628. $C_{15}H_{21}NO$ requires *M*, 231.1623); *m/z* 231 (8%), 1 236 (18, *M* − Me), 188 (14, *M* − Pr), 110 (24, *M* − $PhCONH_2$), 105 (100, $PhCO^+$), and 77 (32, Ph^+).

(E)-N-(2,5-*Dimethylhex*-3-*en*-2-*yl*)*benzamide E*-(**32b**).—Similarly, the alcohol *threo*-(**31b**) (275 mg), sodium hydride (50% dispersion; 28 mg) in DMF (20 ml) gave the *amide E*-(**30b**) (128 mg, 84%), as needles, m.p. 107—108 °C (from hexane), R_F-(Et_2O) 0.71; $\nu_{max.}$(Nujol) 3 250 (NH), 1 635 (C=O I) 1 540 (C=O II), and 965 cm^{-1} (CH=CH out-of-plane deformation); $\delta(CDCl_3)$ 7.30—7.55 and 7.70—7.90 (5 H, m, Ph), 6.10 (1 H, br s, NH), 5.81 (1 H, d, *J* 16 Hz, NCC*H*=CH), 5.56 (1 H, dd, *J* 6, 16 Hz, CH=C*H*CH), 2.29 (1 H, septet, *J* 6 Hz, Me_2CH), 1.56 (6 H, s, Me_2C), and 1.02 (6 H, d, *J* 6 Hz, Me_2CH) (Found: M^+, 231.1611. $C_{15}H_{21}NO$ requires *M*, 231.1623); *m/z* 231 (10%), 216 (16, *M* − Me), 188 (11, *M* − Pr), 110 (21, *M* − $PhCONH_2$), 105 (100, $PhCO^+$), and 77 (26, Ph^+).

N-(4-*Methylpent*-3-*en*-2-*yl*)*benzamide* (**28a**).—Similarly, the alcohol (**27a**) (180 mg) and sodium hydride (50% dispersion; 30 mg) in DMF (20 ml) gave the *amide* (70 mg, 80%), as needles, m.p. 85—86 °C (from EtOAc–hexane), $R_F(Et_2O)$ 0.66; $\nu_{max.}$-($CDCl_3$) 3 425 (NH I), 3 300 (NH II), 1 640 (C=O I) and 1 500 cm^{-1} (C=O II); $\delta(CDCl_3)$ 7.65—7.83 and 7.20—7.50 (5 H, m, Ph), 6.20 (1 H, br s, NH), 5.14 (1 H, distorted d, *J* 7.5 Hz, C=CH), 4.94 (1 H, quintet, *J* 7.5 Hz, CHN), 1.72 (6 H, distorted s, Me_2C=CH), and 1.27 (3 H, d, *J* 7.5 Hz, *Me*CH) (Found: M^+, 203.1295. $C_{13}H_{17}NO$ requires *M*, 203.1310); *m/z* 203 (2%), 122 (3, $PhCONH_2^+$), 105 (100, $PhCO^+$), and 77 (61, Ph^+).

(Z)-N-(*But*-3-*en*-*yl*)*benzamide Z*-(**30**).—Similarly, the alcohol *erythro*-(**29**) (186 mg) and sodium hydride a (50% dispersion; 25 mg) in DMF (20 ml) gave the *amide* (71 mg, 82%), as needles, m.p. 82—83 °C (from EtOAc); R_F (Et_2O) 0.64; $\nu_{max.}$(Nujol) 3 295 (NH), 1 623 (C=O I), and 1 535 cm^{-1} (C=O II); $\delta(CDCl_3)$ 7.30—7.90 (5 H, m, Ph), 6.20 (1 H, br s, NH), 5.25—5.80 (2 H, m, CH=CH), 4.90—5.25 (1 H, quintet, *J* 7 Hz, NCH), 1.73 (3 H, d, *J* 7 Hz, *Me*CH=CH), and 1.30 (3 H, d, *J* 7 Hz, CH_3CHN) [irradiation at 1.73 simplifies the peak at 5.25—5.80 to: 5.59 (1 H, d, *J* 11 Hz, MeC*H*=CH) and 5.37 (1 H, dd, *J* 11, 7 Hz, MeCH=C*H*)] (Found: M^+, 189.1159. $C_{12}H_{15}NO$ requires *M*, 189.1154), *m/z* 189 (15%, M^+ 105 (100, $PhCO^+$), and 77 (40, Ph^+).

(E)-N-(*But*-3-*en*-2-*yl*)*benzamide E*-(**30**).—Similarly, the alcohol *threo*-(**29**) (163 mg) and sodium hydride (50% dispersion; 25 mg) in DMF (20 ml) gave the amide *E*-(**28**) (57 mg, 76%), as needles, m.p. 61—63 °C (from EtOAc); R_F (Et_2O) 0.65, $\nu_{max.}$(Nujol) 3 275 (NH), 1 623 (C=O I), 1 527 (C=O II), and 965 cm^{-1} (C=C); $\delta(CDCl_3)$ 7.24—7.90 (5 H, m, Ph), 6.34 (1 H, br s, NH), 5.35—5.87 (2 H, m, CH=CH), and 1.28 (3 H, d, *J* 7 Hz, *Me*CHN) [irradiation at 1.67 simplifies the peak at 5.35—5.87 to: 5.74 (1 H, d, *J* 16 Hz, MeC*H*=CH) and 5.53 (1 H, dd, *J* 7, 16 Hz, MeCH=C*H*)] (Found: M^+, 189.1160. $C_{12}H_{15}NO$ requires *M*, 189.1154); *m/z* 189 (69%, M^+), 105 (100, $PhCO^+$), 84 (75, $C_5H_{10}N^+$), and 77 (70, Ph^+).

3-*Diphenylphosphinoyl*-3-*methyl*-4-*piperidinobutan*-1-*ol* (**38**).—BuLi (0.22 ml) was added to a stirred solution of the amine (**13**) (109 mg) in LiBr-saturated Et_2O (15 ml) at 0 °C. After being stirred for 15 min, the solution was cooled to −78 °C and acetaldehyde (0.1 ml) added. Stirring was continued for 10 min, after which saturated aqueous ammonium chloride was added to quench the reaction; the mixture was then diluted with water (100 ml) and extracted with CH_2Cl_2 (3 × 50 ml). The combined organic layers were dried ($MgSO_4$), evaporated under reduced pressure, and the residue purified by p.l.c. eluting with EtOAc–Et_3N–EtOH (94:1:5) to give the *alcohol* as a mixture of diastereoisomers (58 mg, 50.5%), as needles, m.p. 142—145 °C (decomp.) (from EtOAc) (Found: C, 71.1; H, 8.05; N, 4.0. $C_{22}H_{30}NO_2P$ requires C, 71.2; H, 8.10; N, 3.8%); R_F (EtOAc–EtOH–Et_3N, 94:5:1) 0.30, 0.35; $\nu_{max.}(CDCl_3)$ 3 100 (OH), 1 435 (P–Ph), and 1 170 cm^{-1} (P=O); $\delta_H(CDCl_3)$ 7.15—8.13 (10 H, m, Ph_2PO), 5.5—7.0 (1 H, br s, OH), 3.70—4.38 (1 H, m, C*H*OH), 2.20—3.28 (6 H, m, NCH_2), and 0.83—2.00 (12 H, m, $NCH_2CH_2CH_2$ and Me); *m/z* 286 (1.0%, *M* − $C_5H_{10}NH$), 243 [18, $Ph_2P(O)C(CH_2)Me^+$], and 217 (100, $Ph_2PO_2^+$).

1-(3-*Diphenylphosphinoyl*-2-*methylenebutyl*)*piperidine* (**39**).—TsOH (49 mg) was heated under reflux in benzene with azeotropic removal of water for 2 h after which the solution was cooled, and the alcohol (**38**) (59 mg) added to it. Heating under reflux was continued for 20 h after which the solution was again cooled, evaporated under reduced pressure, and the residue purified by p.l.c. (double elution with EtOAc–Et_3N–EtOH, 94:1:5) to give the *amine* (21 mg, 37%) as a pale yellow oil, R_F (EtOAc–Et_3N–EtOH, 94:1:5) 0.2; $\nu_{max.}(CDCl_3)$ 1 440 (P–Ph) and 1 180 cm^{-1} (P=O); $\delta_H(CDCl_3)$ 7.35—8.08 (10 H, m, Ph_2PO), 5.38 (1 H, d, J_{PH} 3 Hz, CH_AH_B=C), 5.19 (1 H, d, J_{PH} 4 Hz, CH_B), 3.61 (1 H, dq, J_{HH} 7.5, J_{HP} 15 Hz, CHP), 1.95—2.81 (4 H, m, NCH_2CH_2), 2.57 (2 H, br s, NCH_2C=CH_2), 1.01—1.60 (6 H, m, $NCH_2CH_2CH_2$), and 1.37 (3 H, dd, J_{HH} 7.5, J_{PH} 18 Hz, Me) (Found: M^+, 353.1896. $C_{22}H_{28}NOP$ requires *M*, 383.1906); *m/z* 353 (0.1%), 202 (20, Ph_2POH^+), 201 (22, Ph_2PO^+), and 152 (100, *M* − Ph_2PO).

4-*Benzamido*-3-*diphenylphosphinoyl*-3-*methylbutan*-2-*ol* (**43**).—BuLi (12 ml) was added to a stirred solution of the amide (**42**) (3.24 g) in LiBr-saturated THF (100 ml) at −40 °C and stirring continued for 15 min. The reaction mixture was cooled to −78 °C, acetaldehyde (0.51 ml) was added, and stirring continued for 15 min. The reaction was quenched with aqueous ammonium chloride and the mixture diluted with water (200 ml) and extracted with CH_2Cl_2 (3 × 150 ml). The combined organic layers were dried ($MgSO_4$), evaporated under reduced pressure, and the oil purified by flash chromatography eluting with EtOAc–Et_3N–hexane (87:3:10) to give the *alcohol* (2.43 g, 65%) as a mixture of diastereoisomers as a clear oil, R_F (EtOAc–Et_3N, 97:3) 0.23, 0.32; $\nu_{max.}(CDCl_3)$ 3 600, 3 400, 3 320 (OH, NH), 1 650 (C=O I), 1 530 (C=O II), 1 435 (P–Ph), and 1 160 cm^{-1} (P=O); $\delta_H(CDCl_3)$ (one diastereoisomer) 8.43 (1 H, t, *J* 5 Hz, NH), 7.42—8.25 (15 H, m, Ph), 4.30 (1 H, s, OH), 4.10 (1 H, dq, J_{HH} 7, J_{HP} 9 Hz, C*H*OH), 3.59 (2 H, dd, J_{HH} 5, J_{PH} 9 Hz, CH_2N), 1.24 (3 H, d, *J* 16 Hz, PMe), and 1.16 (3 H, d, *J* 7 Hz, *Me*COH) (Found: M^+ − Me, 392.1429. $C_{23}H_{23}NO_3P$ requires *M* − Me, 392.1415); *m/z* 392 (0.07%, *M* − Me), 363 (38, *M* − MeCHO), 306 (100, *M* − Ph_2PO), 202 (90, Ph_2POH^+), and 201 (60, Ph_2PO^+).

5-*Diphenylphosphinoyl*-5,6-*dimethyl*-2-*phenyl*-5,6-*dihydro*-4H-1,3-*oxazine* (**44**).—A solution of the alcohol (**43**) (300 mg) (as a mixture of diastereoisomers) and TsOH (100 mg) in benzene (25 ml) was heated under reflux for 24 h with azeotropic removal of water; the mixture was then cooled, poured onto saturated aqueous sodium hydrogen carbonate (25 ml), and the layers separated. The aqueous layer was extracted with CH_2Cl_2 (3 × 25 ml) and the combined organic layers dried ($MgSO_4$) and evaporated under reduced pressure to give the *oxazine* (178 mg, 62%), as needles, m.p. 178—178.5 °C (from EtOAc) (Found: C, 73.7; H, 6.4; N, 3.85. $C_{24}H_{24}NO_2P$ requires C, 74.0; H, 6.20; N, 3.60%); R_F (EtOAc) 0.32; $\nu_{max.}(CDCl_3)$ 2 960 (CH), 1 658 (C=N), 1 440 (P–Ph), and 1 200 cm^{-1} (P=O); $\delta_H(CDCl_3)$ 7.18—

7.53 and 7.83—8.14 (15 H, m, Ph), 4.57 (1 H, dq, J_{HH} 7, J_{HP} 10 Hz, CHO), 4.05 (1 H, dd, J 9, 16.5 Hz, CH_AH_BN), 3.15 (1 H, dd, J 4.5, 16.5 Hz, CH_AH_BN), 1.27 (3 H, d, J 7 Hz, *Me*CH), and 1.25 (3 H, d, J 15 Hz, *Me*CP); *m/z* 389 (3%, M^+), 201 (24, Ph_2PO^+), 188 (87, $M - Ph_2PO$), and 105 (100, $PhCO^+$).

4-*Benzamido*-3-*diphenylphosphinoyl*-3-*methylpentan*-2-*ol* (**46**).—Similarly, the amide (**44**) (1.19 g) and BuLi (4.1 ml) in LiBr-saturated THF (10 ml) with acetaldehyde (0.5 ml) gave an oil which was separated by h.p.l.c. (EtOAc–Et_3N, 97:3) to give the HR_F diastereoisomer of the alcohol mixed with the starting amide (estimated alcohol:amide 67:33 by n.m.r.) (total 400 mg, estimated 21% yield of alcohol) and the LR_F diastereoisomer of the *alcohol* (330 mg, 25%), as prisms, m.p. 219—222 °C (decomp.) (from EtOAc) (Found: C, 70.9; H, 6.70; N, 3.3. $C_{25}H_{28}NO_3P$ requires C, 71.3; H, 6.65; N, 3.3%); R_F (EtOAc–Et_3N, 97:3) 0.30; $\nu_{max.}$($CDCl_3$) 3 350 (OH, NH), 1 650 (C=O I), 1 530 (C=O II), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ_H($CDCl_3$) 7.30—8.55 (16 H, m, Ph and NH), 3.80—5.10 (3 H, m, C*H*O*H* and N*H*), and 1.05—1.55 (9 H, m, Me); *m/z* 377 (28%, M − MeCHO), 274 (28, MH − PhCONHCHMe), 202 (40, Ph_2POH), 201 (40, Ph_2PO), and 105 (100, $PhCO^+$).

5-*Diphenylphosphinoyl*-4,5,6-*trimethyl*-2-*phenyl*-5,6-*dihydro*-4H-1,3-*oxazine* (**47**).—Similarly, the alcohol (**46**) (240 mg) and TsOH (200 mg) in benzene (25 ml) under reflux (72 h) gave the *oxazine* (149 mg, 65%) as needles, m.p. 219—220 °C (decomp.) (from CH_2Cl_2–hexane); R_F (EtOAc–Et_3N, 97:3) 0.45; $\nu_{max.}$($CDCl_3$) 1 655 (C=N), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ_H($CDCl_3$) 7.29—8.24 (15 H, m, Ph), 4.20—4.74 (2 H, m, NCH and OCH), 1.15—1.52 (6 H, m, *Me*CP and *Me*CHN or *Me*CHO), and 0.76 (3 H, d, J 7 Hz, *Me*CHN or *Me*CHO) (Found: MH$^+$, 404.1752. $C_{25}H_{27}NO_2P$ requires MH, 404.1779); *m/z* 404 (0.6%, MH$^+$), 257 [27, $Ph_2P(O)C_4H_8^+$], 202 (100, Ph_2POH^+), and 201 (17, Ph_2PO^+).

1-*Dimethylamino*-3-*diphenylphosphinoyl*-2-*methylpropan*-2-*ol* (**48**).—BuLi (3.25 ml) was added dropwise to a stirred solution of methyldiphenylphosphine oxide (1.08 g) in LiBr-saturated THF (70 ml) at 0 °C and stirring continued for 15 min. The solution was cooled to −78 °C and dimethylaminoacetone (0.57 ml) added *via* a syringe. Stirring was continued for 15 min after which the reaction was quenched by the addition of aqueous ammonium chloride followed by water (100 ml). The mixture was extracted with CH_2Cl_2 (3 × 75 ml) and the combined organic layers were extracted into 0.1M HCl (2 × 75 ml); the aqueous layers were adjusted to pH 11 with 30% (w/v) aqueous sodium hydroxide, and extracted with CH_2Cl_2 (3 × 75 ml). The combined organic layers were dried ($MgSO_4$) and evaporated under reduced pressure to give the *alcohol* (1.20 g, 76%) as needles, m.p. 121—123 °C (decomp.) (from EtOAc–hexane), R_F (EtOAc–Et_3N, 97:3) 0.10; $\nu_{max.}$(Nujol) 3 370 (OH), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ_H($CDCl_3$) 7.30—7.97 (10 H, m, Ph_2PO), 4.80 (1 H, s, OH) (disappears on shaking with D_2O), 2.35—3.10 (4 H, m, PCH_2, NCH_2), 2.28 (6 H, s, NMe_2), and 1.19 (3 H, s, *Me*COH) (Found: M, 317.1539. $C_{18}H_{24}NO_2P$ requires M, 317.1544); *m/z* 317 (0.14%), 299 (8, $M - H_2O$), 259 [100, $Ph_2P(O)CH_2C(OH)Me^+$], and 201 (40, Ph_2PO^+).

(E)-1-(3-*Diphenylphosphinoylprop*-2-*enyl*)*piperidine* (**51a**).—Piperidine (dry) (5 ml) was added to a stirred solution of the dibromide[26] (**21**) (3.17 g) in chloroform (50 ml) at room temperature and stirring continued for 4 h. The mixture was poured onto saturated aqueous sodium hydrogen carbonate (50 ml), the layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (50 ml). The combined organic layers were dried ($MgSO_4$) and evaporated under reduced pressure to give the *amine* as needles (2.00 g, 79%), m.p. 103.5—104.5 °C (from CH_2Cl_2–Et_2O) (Found: C, 73.7; H, 7.55; N, 4.2. $C_{20}H_{24}NOP$ requires C, 73.8; H, 7.4; N, 4.3%); R_F (EtOAc–Et_3N, 97:3) 0.05; $\nu_{max.}$($CDCl_3$) 1 635 (C=C), 1 440 (P–Ph), 1 180 (P=O), and 970 cm^{-1} (HC=CH out-of-plane deformation); δ($CDCl_3$) 7.32—7.86 (10 H, m, Ph_2PO), 6.26—7.10 (2 H, m, PCHCH), 3.16 (2 H, dd, J_{HH} 5, J_{HP} 2 Hz, NCH_2CH), 2.23—2.46 (4 H, m, NCH_2), and 1.25—1.72 (6 H, m, $NCH_2CH_2CH_2$); irradiation at δ 3.16 simplifies the vinyl region to 6.76 (1 H, dd, J_{HH} 17, J_{HP} 24 Hz, PCCH), and 6.53 (1 H, dd, J_{HH} 17, J_{HP} 28 Hz, PCH) (Found: M^+, 325.1584. $C_{20}H_{24}NOP$ requires M, 325.1596); *m/z* 325 (0.6%), 242 [100, $Ph_2P(O)CH_2CHCH_2^+$], and 124 (33, $M - Ph_2PO$).

(E)-1-(3-*Diphenylphosphinoylprop*-2-*enyl*)*morpholine* (**51b**).—Morpholine (10 ml) and the dibromide[7] (**21**) (11.7 g) in CH_2Cl_2 (40 ml) gave the *amine* (7.5 g, 79%) as needles, m.p. 125—127 °C (decomp.) (from CH_2Cl_2–Et_2O), R_F (EtOAc–Et_3N, 97:3) 0.05; $\nu_{max.}$(Nujol) 1 635 (C=C), 1 440 (P–Ph), and 1 180 cm^{-1} (P=O); δ_H($CDCl_3$) 7.31—7.90 (10 H, m, Ph_2PO), 6.23—7.00 (2 H, m, PCHCH), 3.66 (4 H, t, J 4.5 Hz, CH_2O), 3.18 (2 H, dd, J 3, 7 Hz, NCH_2CH), and 2.42 (4 H, complex t, J 4.5 Hz, NCH_2CH_2); irradiation at δ 3.18 simplifies the vinyl region to 6.74 (1 H, dd, J 17, 21 Hz, PCCH) and 6.51 (1 H, dd, J 17, 25 Hz, PCH) (Found: M^+, 327.1387. $C_{19}H_{22}NO_2P$ requires M, 327.1388); *m/z* 327 (1.8%), 242 [100, $Ph_2P(O)CH_2CHCH_2^+$], and 241 [28, $Ph_2P(O)CHCHCH_2^+$].

(N-*Methylbenzamido*)*acetone* (**54**).—A mixture of *N*-benzoylsarcosine[34] (**53**) (46.5 g), 4-*N*,*N*-dimethylaminopyridine (0.25 g), pyridine (50 ml), and acetic anhydride (50 ml) was heated under reflux for 2.5 h (oil bath at 140 °C). The crude reaction mixture was distilled to give the *ketone* (30.5 g, 66%) as an oil, b.p. 155—158 °C/0.25 mmHg (Found: C, 69.0; H, 6.8; N, 7.5. $C_{11}H_{13}NO_2$ requires C, 69.2; H, 6.8; N, 7.3%); R_F (EtOAc) 0.24; $\nu_{max.}$(liq. film) 3 500 (OH enol form), 1 725 (C=O ketone), and 1 640 cm^{-1} (C=O amide); δ_H($CDCl_3$) 7.44 (5 H, br s, Ph), 4.28 and 4.06 (total 2 H, 2 × s, NCH_2), 2.96 (3 H, br s, NMe), and 2.13 and 1.90 (total 3 H, 2 × br s, MeCO); *m/z* 191 (10%), 179 (6, M − Me), 148 (33, M − Ac), 105 (100, $PhCO^+$), and 77 (33, Ph^+).

3-*Diphenylphosphinoyl*-2-*methyl*-1-(N-*methylbenzamido*)-*propan*-2-*ol* (**55**).—Similarly, methyldiphenylphosphine oxide (1.26 g) and BuLi (3.9 ml) in LiBr-saturated THF (25 ml) with the ketone (**32**) (1.11 g) gave an oil which crystallised and was recrystallised to give the *alcohol* (1.855 g, 78%) as prisms, m.p. 158—158.5 °C (from CH_2Cl_2–Et_2O) (Found: C, 71.0; H, 6.65; N, 3.35. $C_{24}H_{26}NO_3P$ requires C, 70.8; H, 6.4; N, 3.4%); R_F (EtOAc) 0.37; $\nu_{max.}$($CDCl_3$) 3 280 (OH), 1 625 (amide CO), and 1 442 (PPh); δ_H($CDCl_3$) 7.32—8.01 (15 H, m, Ph_2PO and PhCO), 5.52 (1 H, br s, OH), 3.91 (1 H, d, J 14 Hz, NCH_AH_B), 3.53 (1 H, d, J 14 Hz, CH_AH_B), 3.15 (3 H, s, MeN), and 1.27 (3 H, s, *Me*COH), *m/z* 408 (19%, MH$^+$), 406 (13, M − H), 389 (37, M − H_2O), 259 [100, $Ph_2P(O)CH_2C(OH)Me^+$], and 201 (60, Ph_2PO^+).

N-(3-*Diphenylphosphinoyl*-2-*methylprop*-1-*enyl*)-N-*methylbenzamide* (**57**).—The alcohol (**55**) (1.0 g) was added over 5 min to vigorously stirred sulphuric acid (7.5 ml) at 0 °C, and the solution allowed to reach room temperature (20 min). The mixture was then poured onto ice (50 g) and extracted with dichloromethane (3 × 50 ml). The combined extracts were dried ($MgSO_4$) and evaporated to give an oil. t-Butyl alcohol (50 ml) was added and any remaining dichloromethane azeotroped off. After addition of further t-butyl alcohol (50 ml) the flask was flushed with nitrogen and KOBu^t (50 mg) was added. The mixture was stirred at 25 °C for 16 h after which it

was poured into saturated aqueous NH_4Cl and extracted with dichloromethane (3 × 75 ml). The combined organic layers were dried ($MgSO_4$) and evaporated. P.l.c. on silica, eluting twice with EtOAc, gave the *amide* (0.69 g, 72%), an oil, R_F (EtAOc) 0.15; $\nu_{max.}(CDCl_3)$ 3 060, 1 640 (C = O), 1 440 (PPh), and 1 190 cm^{-1} (P=O); $\delta_H(CDCl_3)$ 7.25—7.89 (15 H, m, Ph), 5.94 (1 H, br d, J_{HP} 5 Hz, NCH), 2.93 (2 H, d, J_{HP} 14 Hz, PCH_2), 2.90 (3 H, s, NMe), and 1.55 (3 H, br s, Me) (Found: M^+, 389.1529. $C_{24}H_{24}NO_2P$ requires *M*, 389.1545), *m/z* 389 (2.5%, M^+), 284 (59, *M* − PhCO), 215 [47, $Ph_2P(O)CH_2^+$], 202 (39, Ph_2POH^+), 201 (100, Ph_2PO^+), and 188 (38, *M* − Ph_2PO).

1-N-*Methylbenzamido*-2-*methyl*-4-*phenylbuta*-1,3-*diene* (**59**).—The amide (**36**) (466 mg) in THF (20 ml) with lithium di-isopropylamide [from di-isopropylamine (0.25 ml) and BuLi (1.0 ml), in THF (10 ml), excess] at −78 °C gave a deep red solution which was quenched with benzaldehyde (0.2 ml, excess) at −78 °C to −10 °C (20 min). Saturated aqueous NH_4Cl was added and the orange solution extracted with dichloromethane (100 then 50 ml). The combined organic layers were washed with brine (50 ml), dried ($MgSO_4$), and evaporated to give an oil. P.l.c. on silica, eluting with EtOAc, gave starting material (95 mg), a Ph_2PO-containing compound, probably the Horner–Wittig adduct (**58**) (54 mg), and the *dienamide* (161 mg), R_F 0.6 (EtOAc); $\nu_{max.}(CDCl_3)$ 1 630 (CO); $\delta_H(CDCl_3)$ 7.2—7.6 (10 H, m, Ph), 6.65 (1 H, d, *J* 15 Hz, *trans* C*H*–CH), 6.50 (1 H, d, *J* 15 Hz, *trans* CH=C*H*), 6.32 (1 H, br s, C=CHN), 3.23 (3 H, s, NMe), and 1.71 (3 H, s, CMe) (Found: M^+, 277.1475. $C_{19}H_{19}NO$ requires *m*, 277.1466), *m/z* 277 (11%, M^+), 172 (11, *M* − PhCO), 105 (100, $PhCO^+$), and 77 (45, Ph^+).

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