Pergamon

Tetrahedron 54 (1998) 12923–12952

TETRAHEDRON

Metallation of Benzylic Amines via Amine-Borane Complexes

Mark R. Ebden and Nigel S. Simpkins*

Department of Chemistry, University of Nottingham, University Park, Nottingham NG7 2RD, U.K.

and David N. A. Fox

Department of Discovery Chemistry, Pfizer Central Research, Sandwich, Kent CT13 9NJ, U.K.

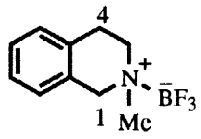
Received 10 July 1998; revised 3 August 1998; accepted 13 August 1998

Abstract: Formation of borane complexes of *N,N*-dimethylbenzylamine, *N,N*-dimethyl(1-naphthyl)methylamine, *N,N*-dimethyl(2-naphthyl)methylamine, *N* -methyltetrahydroisoquinoline and *N*-methylisoindoline facilitates regioselective metallation of these systems using BuLi, giving intermediate benzylic anions which react with a range of electrophiles to give products in good yield.

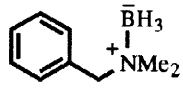
INTRODUCTION

In 1991 Kessar and co-workers described how the use of BF_3 as a Lewis acid activator facilitated the α-metallation of a range of tertiary amines, including benzylic, allylic and even saturated types, using either lithium tetramethylpiperidide (LTMP) or ^{s}BuLi.[1,2] In some cases the Lewis acid complexes showed contrasting regiochemistry in their metallation reactions compared to the uncomplexed amines. For example, complex **1** (formed *in situ*) underwent metallation and electrophilic substitution at C-1, whereas the corresponding free amine usually reacts at C-4.

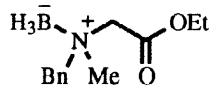
We became interested in this approach to amine substitution, and recently described some preliminary results which demonstrated that isolable borane complexes, such as **2**, also undergo interesting metallation reactions.[3] Recent reports from the group of Gall and Mioskowski, which described enolate chemistry of amine–borane complexes **3** and **4**, have further extended the utility of these complexes.[4,5]



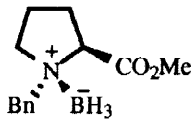
(1)



(2)



(3)



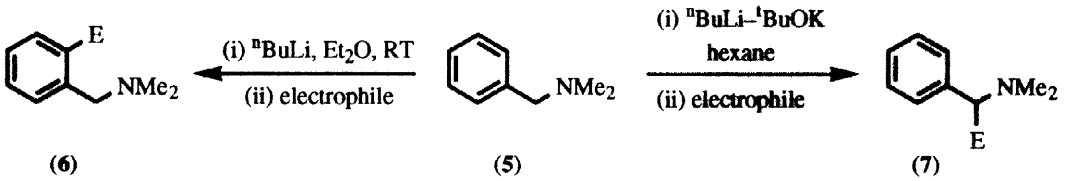
(4)

Herein we describe our results in the area of tertiary amine metallation in full, including studies of naphthyl-substituted systems not described in our earlier communication.

0040-4020/98/$ - see front matter
PII: S0040-4020(98)00783-2

RESULTS AND DISCUSSION

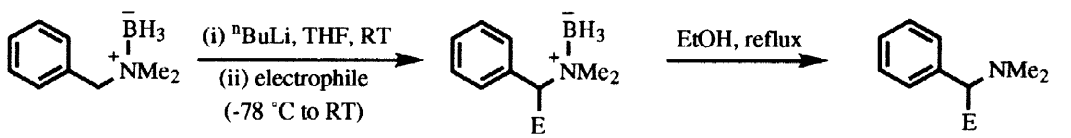
We initially focused on *N,N*-dimethylbenzylamine **5** as a substrate for metallation studies. Metallation of this substrate with ^{n}BuLi is reported to proceed slowly in Et_2O at room temperature to give exclusively *ortho*-substituted products **6**, whereas access to α-substituted products **7** is possible by the use of butylsodium or ^{n}BuLi–^{t}BuOK mixtures.[6]



(6) (5) (7)

We reasoned that borane adduct formation would enhance the CH acidity at the benzylic position in **5** whilst removing the donor ability of the amine lone pair which presumably facilitates *ortho*-lithiation in the free amine. It was therefore anticipated that borane complexation of **5** would promote rapid metallation of the system, and would provide the unusual and less readily accessible benzyl anion regiochemistry. Preliminary experiments showed that both borane and chloroborane react with **5** to give stable, analytically pure, adducts, whilst other boranes, such as $BCl(C_6H_{11})_2$ and BCl_2Ph clearly formed adducts (TLC), but these were not stable to work-up and purification. In subsequent metallation trials the readily available borane adduct **2** proved most amenable to substitution chemistry. Treatment of borane adduct **2** with 2 equivalents of ^{n}BuLi in THF at room temperature (LDA was ineffective), followed by cooling to -78 °C and addition of an appropriate electrophile gave good yields of the desired benzylic substituted products, Table 1.

Table 1: Substitution of Borane Complex 2 via Metallation



(2) (8) (7)

electrophile	D_2O	Me_3SiCl	MeI	EtI	allylBr	BnBr	PhCHO	^{t}BuCHO	PhCOPh	$ClCO_2Me$	CO_2
(2)→(8) (%)	98[a]	70	54	59	64	35	44[b]	-	-	53	-
(8)→(7) (%)	-	90	86	87	92	96	95	-	-	-	-
(2)→(7) (%)[c]	-	71	61	64	-	44	56	62[b]	51	62	59

a - The recovered material showed 76–92% deuterium incorporation by ^{1}H NMR spectroscopy.

b - Only the major (erythro) diastereomer was isolated (see text).

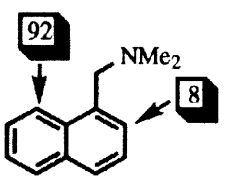
c - Indicates yield of **7** obtained, avoiding isolation of intermediate **8**, by directly heating the crude reaction mixture from the metallation to reflux in EtOH. In the cases of reactions using ^{t}BuCHO, PhCOPh and CO_2 isolation of the intermediate **8** proved difficult.

Examination of the ^1H NMR spectrum of the deuterated product indicated that metallation had indeed proceeded in a highly regioselective fashion at the benzylic (α-position), rather than the *ortho*, position. This was confirmed by close examination of the TLC and NMR spectra of the silylated product **7** (E = $SiMe_3$), which showed no trace of the *ortho*-silylated product, synthesized independently by direct metallation of amine **4**.

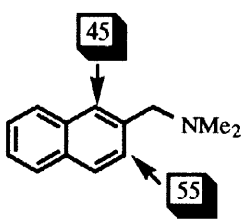
Somewhat surprisingly, efficient metallation of the amine-borane complex requires two equivalents of base. We suspect that this may be partially due to the high affinity of the complexes for water, since many of the product complexes gave analytical data consistent with retention of water of crystallisation. Although in the case of **2** analytically pure, dry, material could be obtained, we still observed lower yields on reducing the amount of base employed. It is also possible that some limited destruction of the borane complexes occurs by nucleophilic attack of ^{n}BuLi, resulting in partial consumption of the base.

Despite this shortcoming, as can be seen from Table 1, the metallated borane complex reacts with a good range of electrophiles to give α-substituted products, it being possible in most cases to isolate complexes **8** in which the borane group is retained. It did not prove possible to carry out a second substitution on the initially formed borane-amine complexes **8** in which an alkyl group had been introduced, and even in the case of **8** (E = $SiMe_3$) we were unable to demonstrate that metallation occurred on exposure to alkyllithium bases.

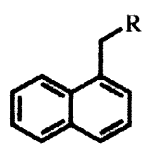
Closely related to the benzylamine system **5** are the corresponding naphthylamine systems **9** and **10**. In these cases deprotonation using ^{n}BuLi again occurs exclusively on the aromatic nucleus, the situation being complicated by metallation at two competing sites in each case (approximate percent metallation at each site is shown).[7]



(9)

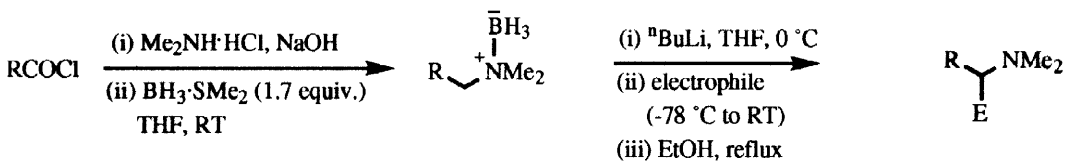


(10)



(15) (a) R = ^{n}Bu
(b) R = ^{s}Bu
(c) R = ^{t}Bu

As in the case of **2**, it was expected that borane complexation would change this outcome and result instead in metallation at the benzylic position. The required amine-borane complexes **11** and **12** were easily prepared by borane reduction of the corresponding amides, themselves prepared routinely from the commercially available acid chlorides.



(11) R = 1-naph.
(12) R = 2-naph.

(13) R = 1-naph.
(14) R = 2-naph.

As anticipated, reaction under our established conditions led to products of benzylic substitution in all cases, with no products from substitution of the naphthalene nucleus being detected, Table 2. Few reactions were carried out using the 1-naphthyl derivative **11**, since in all cases these reactions gave low yields due to a competing displacement reaction of the nitrogen function by ^{n}BuLi to give **15a**. For example, in the case of anion quenching with D_2O, only 50% of deuterated product was recovered, the hydrocarbon **15a** accounting for another 34% of the material. By omitting the usual electrophilic quench, the yield of **15a** could be increased to 60%, and similar treatment of **11** with either ^{s}BuLi or ^{t}BuLi gave rise to the corresponding substitution products **15b** and **15c** in 63% and 58% yields respectively. We have not investigated this process further, but it presumably involves either direct displacement of the amino function, or the intervention of carbenoid intermediates.

In the reactions involving addition to aldehydes, mixtures of isomers were obtained, the degree of stereocontrol being negligible with aldehydes other than PhCHO. As in the analogous reactions involving complex **2**, we have assigned the stereochemistry of the major adduct as *erythro* in each case, based on the established trends in ^{1}H NMR coupling constants in such vicinal aminoalcohols described by Munk *et al.*[8]

Table 2: Substitution of Complexes 11 and 12 via Metallation

electrophile	D_2O	MeI	Me_3SiCl	PhCHO	^{i}PrCHO[b]	cy-hexCHO[b]	PhCOPh	CO_2
(**11**) → (**13**) (%)	50[a]	45	-	-	-	-	40	45
(**12**) → (**14**) (%)	98[a]	66	63	79 (6:1)[c]	74 (1.2:1)[c]	65 (1.2:1)[c]	75	72

a - The recovered material showed *ca.* 100% deuterium incorporation by ^{1}H NMR spectroscopy.

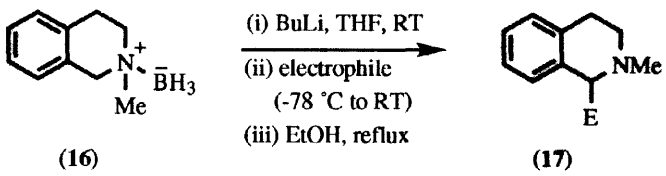
b - Electrophilic quench by inverse addition

c - Diastereoisomer ratio, determined by integration of ^{1}H NMR spectrum of crude reaction mixture.

By contrast, reactions of the 2-naphthyl complex **12** were very efficient, giving a range of substituted amines **14** in very acceptable yields of 63–79%, Table 2. For reasons that are not clear, in the case of enolisable aldehyde partners an inverse quench procedure (anion added by cannula to excess aldehyde) gave higher yields of adduct than the standard method.

We also tested the borane activation method on the borane complex **16**, derived from *N*-methyltetrahydroisoquinoline, one of the amines examined by Kessar and co-workers using BF_3 as the activating Lewis acid. In this system the product borane complexes appeared somewhat unstable, and so we chose to isolate only the product amines **17** (this also avoided the issue of the stereochemical outcome at the reacting carbon centre, relative to the existing asymmetric centre at nitrogen), Table 3.

Table 3: Substitution of Complex 16 via Metallation



(16) (17)

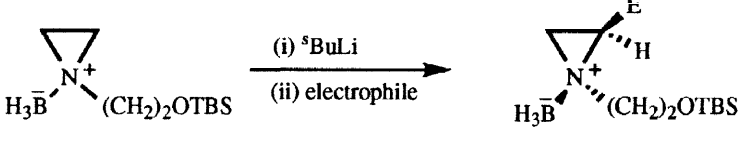
electrophile	D_2O	MeI	Me_3SiCl	PhCHO	$ClCO_2Me$	allylBr	CO_2
(16) → (17) (%)	100[a]	79	64	60[b]	63	59	55

a - The recovered material showed *ca.* 100% deuterium incorporation by ^1H NMR spectroscopy.

b - Two diastereoisomers were obtained in a ratio of 8:1.

As we had hoped, the metallation of **16** shows the same modified regiochemistry previously described for the Lewis acid methodology employing BF_3. In fact the chemical yields of **17** for the reactions shown in Table 3 involving MeI, Me_3SiCl and PhCHO are significantly higher than those quoted for the BF_3 method (taking into account the 94% yield in the separate complex-forming step). This underlines the utility of our method, especially if the borane complexation can also be used as a nitrogen protecting group, or to facilitate handling and purification (since the complexes are usually easily handled solids and are often more amenable to flash chromatography on silica-gel than the free tertiary amines).

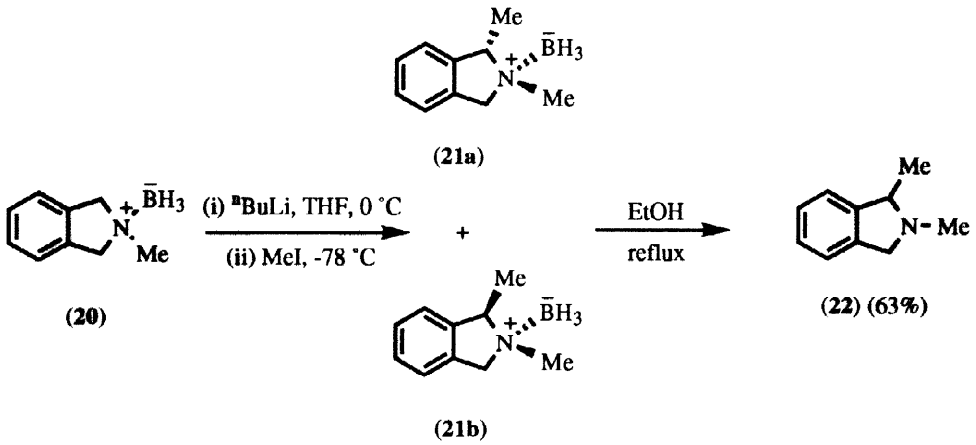
Recently, Vedejs and Kendall showed that the borane activation technique is applicable to aziridines, and that the alkylation chemistry of such systems is highly diastereocontrolled, both the metallation and electrophilic quench occurring *syn* to the BH_3 group, e.g. **18** → **19**.[9]



(18) (19)

In this case the intermediate organolithium was shown to be configurationally stable at the low temperatures employed (-78 °C), and the extent of the *syn*-directing effect was explored using a number of the substituted complexes **19**.

We have described our own, somewhat analogous, preliminary results concerning the stereocontrolled alkylation of the amine–borane complex **20** derived from *N*-methylisoindoline, which appear to follow the same trend.[10]



For example, treatment of the readily accessible *N*-methylisoindoline–borane complex **20** with ^{n}BuLi in THF, followed by addition of methyl iodide, gave the anticipated substituted complexes **21** as a 5:1 mixture of diastereomers favouring **21a**, the isomer alkylated *syn* to boron (75% combined yield). The diastereoselectivity observed in this reaction seems remarkable given the similar sizes of the BH_3 and CH_3 groups, especially since we expect the lithiated intermediate to be configurationally unstable (and therefore the selectivity depends upon the electrophilic quenching step).[11] This situation differs from that found in the aziridine work, where the intermediate is configurationally stable, and the *syn* selectivity is tentatively ascribed to an attraction between the BH_3 group in the complex and the electropositive lithium in the LiC_4H_9 base employed (i.e. the observed selectivity is determined at the deprotonation step).

In conclusion, we have shown that amine-borane complexes, derived from benzylic amines are capable of efficient substitution via metallation, the complexes displaying complementary metallation regiochemistry to the free amines. Studies are presently directed at examining the scope of this approach with non-benzylic amines and to using the method for asymmetric synthesis by employing chiral boranes. The origins of the diastereoselectivity (and the enantioselectivity when ^{s}BuLi–sparteine is employed as base) in the substitution reactions of **20**, along with further applications of this chemistry in the synthesis of chiral amines must await further studies.

Acknowledgements

We are grateful to Pfizer Central Research, Sandwich, U.K., and for a Royal Society of Chemistry Hickinbottom Fellowship, which have provided the funding to support this project.

EXPERIMENTAL

General Details

Melting points were determined on a Reichert Hot Stage apparatus and are uncorrected. Infrared spectra were recorded using a Perkin Elmer 1600 series FTIR spectrophotometer as sample solutions in chloroform or Nujol mulls. High resolution mass spectra were acquired on a VG Micromass 70E or AEI MS-902 mass spectrometer using electron impact (EI), chemical ionization (CI) or fast atom bombardment (FAB) using *meta*-nitrobenzyl alcohol (NBA) as the matrix. Microanalytical data were obtained on a Perkin-Elmer 240B elemental analyser. Proton NMR spectra were recorded on either a Bruker WM 250 (250MHz), a Bruker AM 400 (400MHz) or a Jeol EX-270 (270MHz) spectrometer at ambient temperature. The chemical shifts were recorded relative to an internal tetramethylsilane standard. All coupling constants, *J*, are reported in Hertz. The ratio of isomer mixtures were determined using ^{1}H NMR spectroscopy. Carbon - 13 NMR spectra were recorded on a Jeol EX 270 (68 MHz) spectrometer at ambient temperature. The multiplicities indicated were obtained using a DEPT sequence. Reaction progress was monitored by thin layer chromatography (TLC) using Merck silica gel 60 F_{254} precoated glass plates which were visualised with ultraviolet light and developed by staining with either basic potassium permanganate solution or aqueous ammonium molybdate. Liquid chromatography was performed using forced flow (flash chromatography) of the indicated solvent system on Fluka silica gel 60 (220 - 440 mesh). Solvents were purified by standard techniques prior to use and all other reagents were used as received from commercial suppliers unless otherwise stated.

Preparation of benzyldimethylamine-borane complex 2

BH_3·dimethylsulfide complex (2.28 ml, 1.82 g, 24 mmol) was added dropwise to a stirred solution of freshly distilled *N,N*-dimethylbenzylamine (3.33 ml, 3.00 g, 22.2 mmol) in THF (40 ml) at -78 °C under a N_2 atmosphere. The solution was stirred for 15 min at which time TLC (50 % Et_2O in petroleum ether) showed complete consumption of starting material. Thus the reaction was quenched with water (10 ml) at -78 °C and the mixture allowed to warm to room temperature before pouring into water (50 ml) and diethyl ether (50 ml). The organics were separated and the aqueous layer extracted further with diethyl ether (2 x 50 ml). The organics were then combined, washed with 2N HCl (50 ml), saturated brine (50 ml), dried over $MgSO_4$ and concentrated under reduced pressure to yield **2** as a white solid which was recrystallised from petroleum ether / dichloromethane (10 / 1) to yield analytically pure **2** (3.08 g, 93 %), m.p. 103 °C; (Found: C, 72.37; H,

11.08; N, 9.26. $C_9H_{16}BN$ requires C, 72.53; H, 10.82; N, 9.40 %); υ_{max} ($CHCl_3$)/cm^{-1} 2951, 2366 (B-H), 2320 (B-H), 2273 (B-H), 1468, 1164 and 860; δ_H (250 MHz, $CDCl_3$) 0.8-2.5 (3H, v. br, BH_3), 2.51 (6H, s, N(CH_3)$_2$), 3.99 (2H, s, PhCH_2), and 7.30-7.42 (5H, m, PhH); δ_C (68 MHz, $CDCl_3$) 49.4 (2 x CH_3), 67.2 (CH_2), 128.2 (Ph-CH), 128.8 (Ph-CH), 130.9 (Ph-C) and 132.0 (Ph-CH); *m/z* (EI) 146 (M^+ - 3H, 21%), 135 (M - BH_3, 21) and 91 (M - $N(CH_3)_2$ - BH_3, 100).

General procedure for the substitution of 2 via metallation: silylation to give 8 (E=SiMe$_3$)

A solution of ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) was added dropwise to a solution of complex **2** (154 mg, 1.03 mmol) in THF (10 ml) at -78 °C under a N_2 atmosphere. The solution was then warmed to room temperature for 1h, before recooling to -78 °C and addition of $(CH_3)_3SiCl$ (0.63 ml, 5 mmol, distilled from CaH_2) as a single portion. After 2 min the cooling bath was removed and the reaction mixture allowed to warm to room temperature for 30 min before addition of saturated $NaHCO_3$ solution (10 ml). The phases were separated and the aqueous layer extracted further with diethyl ether (2 x 10 ml). The combined organic extracts were then washed with saturated brine (*ca.* 20 ml), dried over $MgSO_4$ and concentrated under reduced pressure to yield a colourless oil. The crude material was then purified on silica gel (5 % Et_2O in petroleum ether as eluent) to give **8** (E = $SiMe_3$) as a colourless oil which solidified upon drying under high vacuum (161 mg, 70 %), m.p. 40-41 °C; υ_{max} ($CHCl_3$)/cm^{-1} 2951, 2418 (B-H), 2332 (B-H), 2278 (B-H), 1468, 1167, 864 and 840; δ_H (250 MHz, $CDCl_3$) 0.21 (9H, s, Si(CH_3)$_3$), 0.8-2.6 (3H, v. br, BH_3), 2.55 (3H, s, NCH_3), 2.61 (3H, s, NCH_3), 3.55 (1H, s, PhCH), 7.09 (1H, m, PhH), 7.32-7.40 (3H, m, PhH) and 7.52 (1H, m, PhH); δ_C (68 MHz, $CDCl_3$) 1.6 (Si(CH_3)$_3$), 49.8 (NCH_3), 55.1 (NCH_3), 71.9 (CH), 127.8 (Ph-CH), 127.9 (Ph-CH), 128.6 (Ph-CH), 130.5 (Ph-CH), 133.3 (Ph-CH) and 136.0 (Ph-C); *m/z* (EI) 207 (M - BH_3, 5%), 192 (8), 163 (7), 149 (M - $Si(CH_3)_3$, 16), 134 (M - BH_3 - $Si(CH_3)_3$, 100) and 91 (11), (HRMS: found M^+ - BH_3, 207.1432. $C_{12}H_{24}BNSi$ -BH_3 requires M, 207.1443).

Methylation of 2 to give 8 (E = Me)

The general procedure for carbanion formation and substitution was followed using complex **2** (180 mg, 1.21 mmol) in THF (10 ml), ^{n}BuLi (1.51 ml of a 1.6 M solution in hexanes, 2.42 mmol) and methyl iodide (0.38 ml, 6.1 mmol). Purification of the colourless oil by flash chromatography (5 % EtOAc in petroleum ether) gave **8** (E = Me) as a colourless oil (108 mg, 54 %), υ_{max} ($CHCl_3$)/cm^{-1} 2952, 2362 (B-H), 2276(B-H), 1467, 1457 and 1165; δ_H (250 MHz, $CDCl_3$) 0.8-2.5 (3H, v. br., BH_3), 1.74 (3H, d, *J* 7.2,

CHCH_3), 2.45 (3H, s, NCH_3), 2.49 (3H, s, NCH_3), 4.07 (1H, q, *J* 7.2, PhC*H*) and 7.36 (5H, br. s, Ph*H*); δ_C (68 MHz, $CDCl_3$) 16.7 (CH_3), 44.9 (NCH_3), 52.4 (NCH_3), 70.0 (CH), 128.3 (Ph-CH), 128.4 (Ph-CH), 128.8 (Ph-CH), 130.0 (Ph-CH), 132.2 (Ph-CH) and 136.9 (Ph-C); *m/z* (EI) 162 (M^+ - H, 2 %), 160 (2), 149 (M - BH_3, 5), 134 (M - BH_3 - CH_3, 49), 105 (100), 91 (24), and 77 (9), (HRMS: found M^+ - H, 162.1460. $C_{10}H_{18}BN$ - H requires M, 162.1454).

Ethylation of 2 to give 8 (E = Et)

The general procedure for carbanion formation and substitution was followed using complex **2** (149 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and ethyl iodide (0.40 ml, 5 mmol). Purification of the colourless oil by flash chromatography (5 % EtOAc in petroleum ether) gave **8** (E = Et) as a white solid (105 mg, 59 %), m.p. 59-61 °C, (Found: C, 74.82; H, 11.78; N, 7.88. $C_{11}H_{20}BN$ requires C, 74.60; H, 11.38; N, 7.91 %); υ_{max} ($CHCl_3$)/cm^{-1} 2952, 2853, 2417 (B-H), 2364 (B-H), 2275 (B-H), 1466, 1318, 1164, 1002 and 860; δ_H (250 MHz, $CDCl_3$) 0.67 (3H, t, *J* 7.4, CH_2CH_3), 1.94 (1H, ddq, *J* 12.8, 12.2 and 7.4, C*H*HCH$_3$), 2.40 (3H, s, NCH_3), 2.50 (3H, s, NCH_3), 2.75 (1H, dqd, *J* 12.8 7.4 and 3.2, CH*H*CH$_3$), 3.71 (1H, dd, *J* 12.2 and 3.2, PhC*H*) and 7.30-7.41 (5H, m, Ph*H*); δ_C (68 MHz, $CDCl_3$) 11.5 (CH_3), 22.2 (CH_2), 45.5 (NCH_3), 52.7 (NCH_3), 77.0 (CH), 128.2 (Ph-CH), 128.4 (Ph-CH), 128.8 (Ph-CH) and 134.8 (Ph-C); *m/z* (EI) 177 (M^+, 2 %), 167 (27), 149 (M - C_2H_5, 100), 134 (M - BH_3 - C_2H_5, 38), 91 (14) and 71 (43), (HRMS: found M^+, 177.1692. $C_{11}H_{20}BN$ requires M, 177.1689).

Allylation of 2 to give 8 (E = allyl)

The general procedure for carbanion formation and substitution of was followed using complex **2** (149 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and allyl bromide (0.43 ml, 5 mmol). Purification of the oil by flash chromatography (5 % Et_2O in petroleum ether) gave **8** (E = allyl) as a colourless oil (124 mg, 64 %), υ_{max} ($CHCl_3$)/cm^{-1} 2952, 2851, 2419 (B-H), 2359 (B-H), 2277 (B-H), 1643, 1467, 1456, 1162, and 993; δ_H (250 MHz, $CDCl_3$) 0.8-2.5 (3H, v. br., BH_3), 2.44 (3H, s, NCH_3), 2.51 (3H, s, NCH_3), 2.73 (1H, m, PhCHC*H*H), 3.53 (1H, m, PhCHCH*H*), 3.87 (1H, dd, *J* 12.1 and 3.4, PhC*H*), 4.86 (1H, dd, *J* 10.1 and 1.6, CH=C*H*H), 5.02 (1H, dd, *J* 17.0 and 1.6, CH=CH*H*), 5.36 (1H, m, C*H*=CH_2) and 7.26-7.41 (5H, m, Ph*H*); δ_C (68 MHz, $CDCl_3$) 33.8 (CH_2), 45.4 (CH_3), 52.7 (CH_3), 74.7 (CH), 117.6 (CH_2), 128.3 (Ph-CH), 128.9 (Ph-CH), 134.0 (Ph-CH), and 134.3 (Ph-C); *m/z* (EI) 188 (M^+ - H,

2 %), 186 (1), 149 (M - C_3H_5, 3), 134 (M - BH_3 - C_3H_5, 100), 117 (8), 104 (12), 91 (23), and 77 (5), (HRMS: found M^+ - H, 188.1617. $C_{12}H_{20}BN$ - H requires M, 188.1611).

Benzylation of 2 to give 8 (E = benzyl)

The general procedure for carbanion formation and substitution was followed using complex **2** (149 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and benzyl bromide (0.60 ml, 5 mmol). Purification of the oil by flash chromatography (50 % dichloromethane in hexane) gave **8** (E = benzyl) as a white solid (84 mg, 35 %), m.p. 90-91 °C; υ_{max} ($CHCl_3$)/cm^{-1} 2416 (B-H), 2367 (B-H), 2276 (B-H), 1603, 1467, 1163 and 994; δ_H (250 MHz, $CDCl_3$) 0.8-2.35 (3H, v. br., BH_3), 2.44 (3H, s, NCH_3), 2.62 (3H, s, NCH_3), 3.14 (1H, dd, *J* 12.0 and 12.0, PhCH*H*) 4.05 (1H, dd, *J* 12.0 and 2.5, PhC*H*H), 4.18 (1H, dd, *J* 12.0 and 2.5, C*H*N(CH_3)$_2$), and 6.95-7.38 (10H, m, Ph*H*); δ_C (68 MHz, $CDCl_3$) 36.1 (CH_2), 45.4 (CH_3), 52.9 (CH_3), 77.2 (CH), 126.1 (Ph-CH), 128.1 (Ph-CH), 128.3 (Ph-CH), 128.5 (Ph-CH), 128.9 (Ph-CH), 129.2 (Ph-CH), 134.4 (Ph-C) and 138.0 (Ph-C); *m/z* (EI) 239 (M^+, 0.3 %), 206 (5), 181 (M - N(CH_3)$_2$ - BH_3, 38), 165 (9), 134 (100), 118 (5), 104 (11), 91 (21) and 77 (8), (HRMS: found M^+, 239.1847. $C_{16}H_{22}BN$ requires M, 239.1845).

Reaction of 2 with benzaldehyde to give 8 [E = CH(OH)Ph]

The general procedure for carbanion formation and substitution was followed using complex **2** (149 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and benzaldehyde (0.51 ml, 5 mmol). Purification of the oil by flash chromatography (10 % Et_2O in petroleum ether) gave **8** [E = CH(OH)Ph] as a white solid (114 mg, 44 %), υ_{max} ($CHCl_3$)/cm^{-1} 2952, 2417 (B-H), 2352 (B-H), 2276 (B-H), 1467, 1454, 1332, 1163 and 1003; δ_H (250 MHz, $CDCl_3$) 0.9-2.6 (3H, v. br, BH_3), 2.55 (3H, s, NCH_3), 2.61 (1H, d, *J* 6.7, D_2O exchangeable, O*H*), 2.85 (3H, s, NCH_3), 3.84 (1H, d, *J* 2.9, C*H*N(CH_3)$_2$), 6.37 (1H, dd, *J* 6.7 and 2.9, C*H*OH) and 7.01-7.31 (10H, m, Ph*H*); δ_C (68 MHz, $CDCl_3$) 48.6 (CH_3), 54.3 (CH_3), 72.6 (CH), 80.1 (CH), 126.0 (Ph-CH), 127.2 (Ph-CH), 127.7 (Ph-CH), 127.9 (Ph-CH), 128.8 (Ph-CH), 131.2 (Ph-C) and 141.8 (Ph-C); *m/z* (EI) 224 (M^+- BH_3 - OH, 9 %), 196 (31), 134 (100), 105 (10), 91 (11) and 77 (7), (HRMS: found M^+ - OH - BH_3, 224.1441. $C_{16}H_{22}BNO$ - OH and BH_3 requires M, 224.1439).

Reaction of 2 with methyl chloroformate to give 8 (E = CO_2Me)

The general procedure for carbanion formation and substitution was followed using complex **2** (149 mg, 1 mmol) in THF (10 ml), ^nBuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and methyl chloroformate (0.39 ml, 5 mmol). Purification of the oil by flash chromatography (10 % Et_2O in petroleum ether) gave **8** (E = CO_2Me) as a colourless oil (102 mg, 53 %), υ_{max} ($CHCl_3$)/cm^{-1} 2953, 2850, 2417 (B-H), 2373 (B-H), 2280 (B-H), 1742, 1466, 1372, 1151, 1005 and 908; δ_H (250 MHz, $CDCl_3$) 0.75-2.6 (3H, v. br., BH_3), 2.53 (3H, s, NCH_3), 2.87 (3H, s, NCH_3), 3.73 (3H, s, CO_2CH_3), 4.67 (1H, s, PhC*H*) and 7.38-7.58 (5H, m, Ph*H*); δ_C (68 MHz, $CDCl_3$) 46.7 (CH_3), 50.2 (CH_3), 52.3 (CH_3), 73.8 (CH), 128.5 (Ph-CH), 129.3 (Ph-C), 130.3 (Ph-CH), 131.5 (Ph-CH) and 168.7 (C=O); *m/z* (CI) 205 (M^+ - H, 12 %), 194 (M^+ - BH_3, 100), 149 (M^+ - CO_2CH_3), 27), 134 (M^+ - BH_3 - CO_2CH_3, 86), 118 (22), 91 (23) and 77 (9), (HRMS: found M^+ - H, 205.1379. $C_{11}H_{18}BNO_2$ - H requires M, 205.1389).

General procedure for the decomplexation of substituted amine-borane complexes: preparation of 7 (E = $SiMe_3$)[12]

A solution of amine-borane complex **8** (E = $SiMe_3$) (48.6 mg, 0.22 mmol) in EtOH (15 ml) was heated at reflux overnight before TLC (50 % Et_2O in petroleum ether) indicated complete decomplexation of the starting material. The reaction solution was therefore concentrated under reduced pressure and the residue partitioned between diethyl ether (3 ml) and saturated $NaHCO_3$ solution (3ml), the organics were separated and washed further with saturated brine (*ca.* 3ml), dried over $MgSO_4$ and concentrated under reduced pressure to yield a colourless oil **7** (E = $SiMe_3$) (41.0 mg, 90%), υ_{max} ($CHCl_3$)/cm^{-1} 2949, 2821, 2773, 1598, 1488, 1461, 916, 891, 863, and 840; δ_H (250 MHz, $CDCl_3$) 0.04 (9H, s, $Si(CH_3)_3$), 2.32 (6H, s, $N(CH_3)_2$), 2.68 (1H, s, PhC*H*) and 7.12-7.33 (5H, m, Ph*H*); δ_C (68 MHz, $CDCl_3$) -1.2 ($Si(CH_3)_3$), 47.0 ($N(CH_3)_2$), 68.0 (CH), 125.5 (Ph-CH), 128.0 (Ph-CH) and 143.0 (Ph-C); *m/z* (EI) 206 (M^+ - H, 34 %), 177 (16), 161 (12), 134 (M - $Si(CH_3)_3$, 100) and 91 (17), (HRMS: found M^+ - H, 206.1366. $C_{12}H_{21}NSi$ -H requires M, 206.1375).

Decomplexation to give 7 (E = Me)[13]

The general procedure for decomplexation was followed using complex **8** (E = Me) (92 mg, 0.564 mmol) in EtOH (15 ml). Purification of the oil by flash chromatography (5 % MeOH in $CHCl_3$) gave **7** (E = Me) as a yellow oil (72 mg, 86 %), υ_{max} ($CHCl_3$)/cm^{-1} 2926, 2857, 2822, 2778, 1455, 1098 and 952; δ_H (250 MHz, $CDCl_3$) 1.38 (3H, d, *J* 6.5, $CHCH_3$), 2.20 (6H, s, $N(CH_3)_2$), 3.26 (1H, q, *J* 6.5, C*H*$N(CH_3)_2$) and

7.22-7.34 (5H, m, Ph*H*); δ_C (68 MHz, $CDCl_3$) 20.0 (CH_3), 43.0 (2 x NCH_3), 65.9 (CH), 127.0 (Ph-CH), 127.6 (Ph-CH), 128.2 (Ph-CH) and 143.4 (Ph-C); *m/z* (EI) 149 (M^+, 5 %), 134 (M - CH_3, 100), 118 (5), 105 (9), 91 (8) and 77 (5), (HRMS: found M^+, 149.1202. $C_{10}H_{15}N$ requires M, 149.1205).

Decomplexation to give 7 (E = Et)[14]

The general procedure for decomplexation was followed using complex **8** (E = Et) (56 mg, 0.316 mmol) in EtOH (15 ml) to recover amine **7** (E = Et) as a yellow oil (45 mg, 87 %), υ_{max} ($CHCl_3$)/cm^{-1} 2942, 2859, 2824, 2780, 1492, 1456, 1359, 1104, 1003 and 864; δ_H (250 MHz, $CDCl_3$) 0.72 (3H, t, *J* 7.4, CH_2CH_3), 1.74 (1H, m, C*H*HCH$_3$), 1.94 (1H, m, CH*H*CH$_3$), 2.19 (6H, s, N(CH_3)$_2$), 3.06 (1H, dd, *J* 9.7 and 4.7, PhC*H*), 7.20-7.36 (5H, m, Ph*H*); δ_C (68 MHz, $CDCl_3$) 10.9 (CH_3), 26.1 (CH_2), 43.0 (2 x NCH_3), 72.6 (CH), 127.0 (Ph-CH), 128.0 (Ph-CH), 128.6 (Ph-CH) and 140.2 (Ph-C).

Decomplexation to give 7 (E = allyl)[15]

The general procedure for decomplexation was followed using complex **8** (E = allyl) (55 mg, 0.29 mmol) in EtOH (15 ml) to recover amine **7** (E = allyl) as a yellow oil (47 mg, 92 %), υ_{max} ($CHCl_3$)/cm^{-1} 2946, 2825, 2781, 1641, 1455, 1356, 992 and 911; δ_H (400 MHz, $CDCl_3$) 2.19 (6H, s, N(CH_3)$_2$), 2.51 (2H, m, PhCHCH_2), 3.27 (1H, dd, *J* 8.8 and 5.3, PhC*H*), 4.93 (1H, dd, *J* 10.2 and 1.5, CH=C*H*H), 4.98 (1H, dd, *J* 17.4 and 1.5, CH=CH*H*), 5.62 (1H, m, C*H*=CH$_2$), 7.22-7.37 (5H, m, Ph*H*); δ_C (68 MHz, $CDCl_3$) 37.8 (CH_2), 42.7 (2 x CH_3), 70.5 (CH), 116.4 (CH_2), 127.0 (Ph-CH), 127.9 (Ph-CH), 128.6 (Ph-CH), 135.6 (CH) and 139.9 (Ph-C); *m/z* (CI) 176 (M^+ + H, 25 %), 174 (M - H, 22), 146 (11), 134 (M - C_3H_5, 100), 104 (10) and 91 (23), (HRMS: found M^+ + H, 176.1435. $C_{12}H_{17}N$ + H requires M, 176.1439).

Decomplexation to give 7 (E = benzyl)[16]

The general procedure for decomplexation was followed using complex **8** (E = benzyl) (43 mg, 0.179 mmol) in EtOH (15 ml) to recover amine **7** (E = benzyl) as a yellow oil (39 mg, 96 %), υ_{max} ($CHCl_3$)/cm^{-1} 2948, 2862, 2824, 2782, 1603, 1454 and 998; δ_H (250 MHz, $CDCl_3$) 2.26 (6H, s, N(CH_3)$_2$), 2.95 (1H, dd, *J* 12.8 and 9.7, PhC*H*HCH), 3.31 (1H, dd, *J* 12.8 and 4.8, C*H*N(CH_3)$_2$), 3.45 (1H, dd, *J* 9.7 and 4.8, PhCH*H*CH) and 6.93-7.26 (10H, m, Ph*H*); δ_C (68 MHz, $CDCl_3$) 39.9 (CH_2), 42.9 (2 x CH_3), 72.7 (CH), 125.7 (Ph-CH), 127.0 (Ph-CH), 127.8 (Ph-CH), 127.9 (Ph-CH), 128.7 (Ph-CH), 129.2 (Ph-CH), 139.35 (Ph-

C) and 139.4 (Ph-C); *m/z* (EI) 224 (M^+ - H, 40 %), 194 (17), 179 (75), 149 (M - C_6H_5, 100), 134 (M - C_7H_7, 84), 116 (30), 91 (87) and 75 (45). (HRMS: found M^+ - H, 224. 1443. $C_{16}H_{19}N$ - H requires M, 224.1439).

Decomplexation to give 7 [E = CH(OH)Ph][8]

The general procedure for decomplexation was followed using complex **8** [E = CH(OH)Ph] (52.2 mg, 0.205 mmol) in EtOH (15 ml) to recover amine **7** [E = CH(OH)Ph] as an off white solid (47 mg, 95 %), m.p. 85-87 °C (lit.[8], m.p. 87.5-89 °C); υ_{max} ($CHCl_3$)/cm^{-1} 2828, 2784, 1492, 1467, 1454, 1097 and 890; δ_H (250 MHz, $CDCl_3$) 2.35 (6H, s, $N(CH_3)_2$), 3.20 (1H, d, *J* 4.2, $CHN(CH_3)_2$), 5.30 (1H, d, *J* 4.2 CHOH) and 6.94-7.25 (10H, m, Ph*H*); δ_C (68 MHz, $CDCl_3$) 44.1 (2 x CH_3), 72.4 (CH), 77.5 (CH), 126.1 (Ph-CH), 126.8 (Ph-CH), 127.2 (Ph-CH), 127.4 (Ph-CH), 127.5 (Ph-CH), 129.4 (Ph-CH), 136.6 (Ph-C) and 141.1 (Ph-C); *m/z* (CI) 242 (M^+ + H, 16 %), 240 (10), 224 (M - OH, 24), 197 (16), 134 (M - C_7H_7O, 100), 107 (9) and 91 (19), (HRMS: found M^+ + H, 242.1553. $C_{16}H_{19}N$ + H requires M, 242.1545).

Typical procedure for the consecutive substitution–decomplexation of complex 2: preparation of 7 [E = CH(OH)^{t}Bu]

The general procedure for carbanion formation and substitution was followed using **2** (149 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and pivaldehyde (0.54 ml, 5 mmol). The resulting oil was diluted in EtOH (20 ml) and heated at reflux overnight before TLC (50 % Et_2O in petroleum ether) indicated complete decomplexation of the starting material. The reaction mixture was then concentrated under reduced pressure and purified on silica gel (4 % MeOH in $CHCl_3$ as eluent) to yield **7** [E = CH(OH)^{t}Bu] a white solid (137 mg, 62 %), m.p. 81-5 °C; υ_{max} ($CHCl_3$)/cm^{-1} 3253 (O-H), 2949, 2867, 2836, 2791, 1602, 1457, 1359, 1009, 988 and 866; δ_H (250 MHz, $CDCl_3$) 0.74 (9H, s, $C(CH_3)_3$), 2.13 (6H, s, $N(CH_3)_2$), 3.44 (1H, d, *J* 10.0, $CHN(CH_3)_2$), 3.73 (1H, d, *J* 10.0, CHOH), 7.12- 7.16 (2H, m, Ar*H*) and 7.30-7.34 (3H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 26.9 (3 x NCH_3), 34.6 (C), 40.7 (2 x CH_3), 69.7 (CH), 74.3 (CH), 127.4 (Ph-CH), 127.7 (Ph-CH), 130.0 (Ph-CH) and 134 (Ph-C); *m/z* (FAB) 222 (M^+ + H, 100 %), 134 (M - $C_5H_{11}O$, 38), 107 (7), 91 (10), 77 (6) and (69 (5), (HRMS: found M^+ + H, 222.1877. $C_{14}H_{23}NO$ + H requires M, 222. 1858).

Direct synthesis of 7 [E = C(OH)Ph$_2$] from 2[6a]

The general substitution–decomplexation procedure was followed using complex **2** (149 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and benzophenone (0.92 g, 5 mmol) in THF (1.5 ml). Standard decomplexation and purification on silica gel (2 % MeOH in $CHCl_3$ as eluent) gave **7** [E = C(OH)Ph$_2$] as a white solid (161 mg, 51 %), m.p. 107-108 °C (lit.[6a] m.p. 106-107 °C); υ_{max} ($CHCl_3$)/cm^{-1} 3258, 2950, 2832, 2788, 1596, 1492, 1461, 1002 and 971; δ_H (250 MHz, $CDCl_3$) 2.06 (6H, s, N(C*H*$_3$)$_2$), 4.48 (1H, s, C*H*N(CH$_3$)$_2$), 6.86-7.31 (13H, m, Ph*H*) and 7.73 (2H, d, *J* 7.5, Ph*H*); δ_C (68 MHz, $CDCl_3$) 45.8 (2 x CH_3), 77.0 (CH), 78.8 (C), 125.4 (Ph-CH), 126.2 (Ph-CH), 126.4 (Ph-CH), 126.9 (Ph-CH), 127.2 (Ph-CH), 127.4 (Ph-CH), 128.1 (Ph-CH), 130.9 (Ph-CH), 137.9 (Ph-C), 146.0 (Ph-C) and 149.5 (Ph-C); *m/z* (CI) 318 (M^+, 2 %), 300 (M - OH, 3), 182 (8), 167 (5), 134 (100), 118 (14), 105 (22), 91 (13) and 77 (19), (HRMS: found M^+, 318.1853. $C_{22}H_{24}NO$ requires M, 318.1858).

Direct synthesis of 7 (E = CO$_2$Me) from 2[17]

The general substitution–decomplexation procedure was followed using complex **2** (149 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and methyl chloroformate (0.39 ml, 5 mmol). Standard decomplexation and purification on silica gel (20 % EtOAc in petroleum ether as eluent) gave **7** (E = CO_2Me) as a colourless oil (120 mg, 62 %), υ_{max} ($CHCl_3$)/cm^{-1} 2829, 2784, 1738, 1456, 1345, 1153 and 986; δ_H (250 MHz, $CDCl_3$) 2.25 (6H, s, N(C*H*$_3$)$_2$), 3.70 (3H, s, CO_2CH_3), 3.87 (1H, s, C*H*N(CH$_3$)$_2$) and 7.32-7.45 (5H, m, Ph*H*); δ_C (68 MHz, $CDCl_3$) 43.3 (2 x NCH_3), 51.9 (CH_3), 75.0 (CH), 128.3 (Ph-CH), 128.4 (Ph-CH), 128.5 (Ph-CH), 136.2 (Ph-C) and 172.1 (C=O); *m/z* (CI) 192 (M^+ - H, 67 %), 176 (53), 160 (55), 149 (37), 134 (100), 118 (21), 105 (53), 91 (34) and 77 (18). (HRMS: found M^+ - H, 192.1025. $C_{11}H_{15}NO_2$ - H requires M, 192.1025).

Direct synthesis of 7 (E = CO$_2$H) from 2[18]

The general substitution–decomplexation procedure was followed using complex **2** (149 mg, 1 mmol) in THF (10 ml), BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and CO_2 gas (bubbled through the reaction mixture at -78 °C for 10 min). Standard decomplexation gave a solid which was triturated from Et_2O to yield the amino acid **7** (E = CO_2H) as a white solid (105 mg, 59 %), m.p. > 270 °C; (Found: C, 66.81; H, 7.54; N, 7.60. Calc. for $C_{10}H_{13}NO_2$; C, 67.02; H, 7.30; N, 7.82 %); υ_{max} (Nujol mull)/cm^{-1} 2922, 2853,

1624, 1460, 1377, 1150 and 938; δ_H (250 MHz, DMSO) 2.46 (6H, s, N(C*H*$_3$)$_2$), 4.14 (1H, s, C*H*N(CH$_3$)$_2$) and 7.38-7.43 (5H, m, Ar*H*); δ_C (68 MHz, DMSO) 42.7 (2 x CH_3), 76.6 (CH), 130.3 (Ph-CH), 130.4 (Ph-CH), 130.9 (Ph-CH), 134.0 (Ph-C) and 171.5 (C=O); *m/z* (EI) 179 (M^+, 3 %), 134 (M - CO_2H, 100), 118 (31), 91 (41) and 77 (26), (HRMS: found M^+, 179.0954. $C_{10}H_{13}NO_2$ requires M, 179.0946).

Synthesis of theborane complex of N,N-dimethyl-1-naphthylmethylamine ***11***

1-Naphthoyl chloride (5.34 g, 28 mmol) was added portionwise to a biphasic mixture of dimethylamine hydrochloride (6.54 g, 80.1 mmol) and NaOH (4.54 g, 0.114 mol) in H_2O (50 ml) and EtOAc (50 ml) at 0 °C. The reaction mixture was stirred vigorously for 1 h at which time TLC (20 % EtOAc in Et_2O) indicated complete consumption of starting material. Thus the phases were separated and the organic layer washed with 1 M HCl solution (2 x 50 ml), 2 M NaOH solution (50 ml), brine (50 ml) before being dried over $MgSO_4$ and concentrated *in vacuo* to yield the desired amide as an orange oil (5.17 g, 93 %),[19] υ_{max} ($CHCl_3$)/cm^{-1} 3062, 2942, 2869, 2810, 1674 (C=O), 1418, 1234, 1056 and 1026; δ_H (250 MHz, $CDCl_3$) 2.82 (3H, s, NC*H*$_3$), 3.26 (3H, s, NC*H*$_3$), 7.41-7.56 (4H, m, Ar*H*) and 7.78-7.89 (3H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 34.3 (CH_3), 38.3 (CH_3), 123.4 (Ar-CH), 124.4 (Ar-CH), 124.7 (Ar-CH), 125.9 (Ar-CH), 126.5 (Ar-CH), 128.0 (Ar-CH), 128.5 (Ar-CH), 129.0 (Ar-C), 133.0 (Ar-C), 134.3 (Ar-C) and 170.3 (C=O); *m/z* (EI) 199 (M^+, 79 %) 186 (5), 156 (22), 127 (100), 113 (9) 84 (45) and 79 (8); (HRMS: found M^+, 199.0994. $C_{13}H_{13}NO$ requires M, 199.0997).

BH_3·dimethylsulfide complex (3.91 ml, 41.9 mmol) was added dropwise to a stirred solution of the amide prepared as described above (5.00 g, 25.1 mmol) in THF (60 ml) at 0 °C under a N_2 atmosphere. The solution was stirred for 10 min before removing the ice bath and stirring overnight. The solution was then partitioned between saturated NH_4Cl solution (100 ml) and Et_2O (100 ml). The organic layer was separated and the aqueous layer extracted further with diethyl ether (2 x 50 ml). The organics were then combined, washed with saturated brine (100 ml), dried over $MgSO_4$ and concentrated under reduced pressure to yield crude product which was dissolved in a minimum of EtOAc and Et_2O added dropwise to induce crystallisation. The resulting suspension was stored at < 4 °C for 24 hours before filtering to yield complex **11** as a white solid (4.04 g, 81 %), m.p. 103 °C; (Found: C, 78.23; H, 9.18; N, 7.07. $C_{13}H_{18}BN$ requires C, 78.42; H, 9.11; N, 7.03 %); υ_{max} ($CHCl_3$)/cm^{-1} 2952, 2860, 2366 (B-H), 2320 (B-H), 2272 (B-H), 1720, 1466, 1164, 1136 and 1012; δ_H (400 MHz, $CDCl_3$) 1.10-2.40 (3H, v. br., BH_3), 2.53 (6H, s, N(C*H*$_3$)$_2$), 4.55 (2H, s, ArC*H*$_2$), 7.50-7.61 (4H, m, Ar*H*), 7.92 (2H, m, Ar*H*) and 8.13 (1H, d, *J* 8.5, C(2)*H*); δ_C (68 MHz,

$CDCl_3$) 50.1 (2 x CH_3), 62.3 (CH_2), 123.6 (Ar-CH), 124.7 (Ar-CH), 125.8 (Ar-CH), 126.7 (Ar-CH), 127.3 (Ar-C(1)), 129.0 (Ar-CH), 130.0 (Ar-CH), 131.8 (Ar-CH), 133.1 (Ar-C) and 133.8 (Ar-C); *m/z* (EI) 199 (M^+, 2 %) 185 (M - BH_3, 47), 141 (M - $N(CH_3)_2$ - BH_3, 100), 115 (28) and 58 (42).

*Substitution–decomplexation of **11** to give amines **13**: methylation to give **13** (R = Me)*[21]

The general substitution–decomplexation procedure was followed using complex **11** (100 mg, 0.5 mmol) in THF (5 ml), ^{n}BuLi (0.63 ml of a 1.6 M solution in hexanes, 1 mmol) and methyl iodide (0.16 ml, 2.5 mmol). Standard decomplexation and purification on silica gel (2 % Et_2O in petroleum ether then EtOAc as eluents) gave 1-pentylnaphthalene **15a** as an oil (40 mg, 40 %), δ_H (270 MHz, $CDCl_3$) 1.07 (3H, t, *J* 7.0, C*H*$_3$), 1.56 (4H, m), 1.91 (2H, quintet, *J* 7.5), 3.22 (2H, t, *J* 7.5, ArC*H*$_2$), 7.45-7.68 (4H, m, Ar*H*), 7.85 (1H, d, *J* 7.9, Ar*H*), 7.99 (1H, d, *J* 7.6, Ar*H*) and (8.20 (1H, d, *J* 7.6, Ar*H*); δ_C (68 MHz, $CDCl_3$) 14.1 (CH_3), 22.6 (CH_2), 30.6 (CH_2), 32.0 (CH_2), 33.1 (CH_2), 123.9 (Ar-CH), 125.3 (Ar-CH), 125.5 (Ar-CH), 125.6 (Ar-CH), 125.8 (Ar-CH), 126.4 (Ar-CH), 128.7 (Ar-CH), 131.9 (Ar-C), 133.9 (Ar-C) and 139.0 (Ar-C); *m/z* (EI) 198 (M^+, 35 %), 155 (M - C_3H_7, 4), 141 (M - C_4H_9, 100) and 128 (M - C_5H_{11}, 4) and **13** (R = Me) as a colourless oil (45 mg, 45 %) υ_{max} ($CHCl_3$)/cm^{-1} 2948, 2861, 2821, 2776, 1458, 1372, 1096, 948; δ_H (250 MHz, $CDCl_3$) 1.47 (3H, d, *J* 6.6 Hz, CHC*H*$_3$), 2.27 (6H, s, N(C*H*$_3$)$_2$), 4.02 (1H, q, *J* 6.6, C*H*CH$_3$), 7.24-7.53 (3H, m, Ar*H*), 7.59 (1H, d, *J* 7.0, Ar*H*), 7.74 (1H, d, *J* 8.1, Ar*H*) 7.85 (1H, dd, *J* 7.3 and 2.3, Ar*H*) and 8.37 (1H, dd, *J* 7.3 and 1.7, Ar*H*); δ_C (68 MHz, $CDCl_3$) 19.1 (CH_3), 43.5 (2 x NCH_3), 62.2 (CH), 123.8 (Ar-CH), 124.4 (Ar-CH), 125.3 (Ar-CH), 125.4 (Ar-CH), 125.6 (Ar-CH), 127.2 (Ar-CH), 128.8 (Ar-CH), 131.2 (Ar-C), 134.0 (Ar-C) and 140.8 (Ar-C); *m/z* (EI) 199 (M^+, 19 %), 184 (M - CH_3, 100), 168 (5), 155 (M - $N(CH_3)_3$, 32), 127 (6), and 115 (4); (HRMS: found M^+, 199.1358. $C_{14}H_{17}N$ requires M, 199.1361).

*Deliberate displacement of nitrogen using various butyllithiums: 1-Pentylnaphthalene **15a***

A solution of ^{n}BuLi (0.63 ml of a 1.6 M solution in hexanes, 1 mmol) was added dropwise to a solution of complex **11** (100 mg, 0.5 mmol) in THF (5 ml) at -78 °C under a N_2 atmosphere. The solution was then allowed to warm to 0 °C over 1 h, before adding saturated NH_4Cl solution (10 ml). The phases were separated and the aqueous layer extracted further with Et_2O (2 x 10 ml). The combined organic extracts were then washed with saturated brine (*ca.* 20 ml), dried ($MgSO_4$) and concentrated under reduced pressure to yield a yellow oil. Purification on silica gel (2 % EtOAc in petroleum ether as eluent) gave **15a** as a colourless oil (59 mg, 60 %). All data were consistent with those described above.

1-(2-Methyl-1-butyl)naphthalene 15b

A solution of *sec*-BuLi (0.77 ml of a 1.3 M solution in cyclohexane, 1 mmol) was added dropwise to a solution of complex **11** (100 mg, 0.5 mmol) in THF (5 ml) at -78 °C under a N_2 atmosphere. The solution was then allowed to warm to 0 °C over 1 h, before adding saturated NH_4Cl solution (10 ml). The phases were separated and the aqueous layer extracted further with Et_2O (2 x 10 ml). The combined organic extracts were then washed with saturated brine (*ca.* 20 ml), dried ($MgSO_4$) and concentrated under reduced pressure to yield an oil. Purification on silica gel (2 % EtOAc in petroleum ether as eluent) gave **15b** as a colourless oil (62 mg, 63 %), υ_{max} ($CHCl_3$)/cm^{-1} 3065, 2940, 2870, 1510, 1307, 1277 and 1137; δ_H (400 MHz, $CDCl_3$) 0.92 (3H, d, *J* 6.5, $CHCH_3$), 0.98 (3H, t, *J*, 7.5, CH_2CH_3), 1.25 (1H, m), 1.45 (1H, m), 1.86 (1H, m), 2.79 (1H, dd, *J* 12.0 and 6.5, ArC*H*H), 3.14 (1H, dd, *J* 12.0 and 6.5, ArCH*H*), 7.30 (1H, d, *J* 7.0, Ar*H*), 7.41 (1H, t, *J* 7.0, Ar*H*), 7.51 (2H, m, Ar*H*), 7.74 (1H, d, *J* 8.8, Ar*H*), 7.87 (1H, d, *J* 7.5, Ar*H*) and 8.04 (1H, d, *J* 8.8, Ar*H*); *m/z* (EI) 198 (M^+, 23 %), 141 (M - C_4H_9, 100) and 115 (11); (HRMS: found M^+, 198.1404. $C_{15}H_{18}$ requires M, 198.1409).

1-(2,2-dimethylpropyl)naphthalene 15c

A solution of *tert*-BuLi (0.59 ml of a 1.7 M solution in pentane, 1 mmol) was added dropwise to a solution of complex **11** (100 mg, 0.5 mmol) in THF (5 ml) at -78 °C under a N_2 atmosphere. The solution was then warmed to 0 °C for 1 h, before adding saturated NH_4Cl solution (10 ml). The phases were separated and the aqueous layer extracted further with Et_2O (2 x 10 ml). The combined organic extracts were then washed with saturated brine (*ca.* 20 ml), dried ($MgSO_4$) and concentrated under reduced pressure to yield an oil. Purification on silica gel (petroleum ether as eluent) gave **15c** as a colourless oil (58 mg, 58 %), υ_{max} ($CHCl_3$)/cm^{-1} 3048, 2940, 2864, 1510, 1279, 1138 and 1073; δ_H (270 MHz, $CDCl_3$) 1.03 (9H, s, $C(CH_3)_3$), 3.07 (2H, s, $ArCH_2$), 7.33 (1H, d, *J* 7.0, Ar*H*), 7.49 (3H, m, Ar*H*), 7.77 (1H, d, *J* 7.5, Ar*H*), 7.87 (1H, m, Ar*H*) and 8.16 (1H, d, *J* 7.5, Ar*H*); *m/z* (EI) 198 (M^+, 18 %), 183 (M - CH_3, 9) and 142 (M - C_4H_9, 100); (HRMS: found M^+, 198.1410. $C_{15}H_{18}$ requires M, 198.1409).

Reaction of 11 with benzophenone to give 13 [E = C(OH)Ph$_2$]

The general substitution–decomplexation procedure was followed using complex **11** (199 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and benzophenone (0.92 g, 5 mmol). Standard decomplexation and purification on silica gel (2 %, 4 % and 8 % Et_2O in petroleum ether as eluent) gave **13** [E = C(OH)Ph$_2$] as a white solid (145 mg, 40 %), m.p. 108-112 °C; υ_{max} ($CHCl_3$)/cm^{-1} 3275 (O-H), 3088, 3062, 3033, 2957, 2873, 2833, 2789, 1448, 1187, 1055, 1042 and 1034; δ_H (250 MHz, $CDCl_3$) 2.06 (6H, s, N(C*H*$_3$)$_2$), 4.66 (1H, s, ArC*H*), 6.75-7.82 (17H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 45.8 (2 x CH_3), 77.2 (CH), 78.7 (C), 125.4-130.1 (17 x Ar-CH), 132.4 (Ar-C), 132.7 (Ar-C), 135.5 (Ar-C), 145.8 (Ar-C) and 149.5 (Ar-C); *m/z* (CI) 368 (M^+ + 1, 5 %), 323 (9), 223 (34), 200 (14), 184 (100), 163 (65), 141 (4), 105 (15); (HRMS: found M^+ + H, 368.1987. $C_{26}H_{25}NO$ + H requires M, 368.2014).

Reaction of 11 with CO_2 to give 13 (E = CO_2H)

The general substitution–decomplexation procedure was followed using complex **11** (100 mg, 0.5 mmol) in THF (5 ml), ^{n}BuLi (0.625 ml of a 1.6 M solution in hexanes, 1 mmol) and CO_2 gas (bubbled through the reaction mixture at -78 °C for 10 min). Standard decomplexation gave a solid which was triturated from Et_2O to yield the amino acid **13** (E = CO_2H) as a white solid (51.5 mg, 45 %), m.p. 220-3 °C; υ_{max} (Nujol mull)/cm^{-1} 2923, 2853, 1612 (C=O), 1317, 1160, 786; δ_H (270 MHz, D6-DMSO) 2.60 (6H, s, N(C*H*$_3$)$_2$), 5.05 (1H, s, C*H*CO_2H), 7.60 (3H, m, Ar*H*), 7.80 (1H, d, *J* 6.9, Ar*H*), 8.02 (2H, t. apparent, *J* 7.9, Ar*H*) and 8.54 (1H, d, *J* 7.9, Ar*H*); δ_C (68 MHz, $CDCl_3$) 42.1 (2 x CH_3), 70.3 (CH), 124.3 (Ar-CH), 125.4 (Ar-CH), 125.9 (Ar-CH), 126.4 (2 x Ar-CH), 128.6 (Ar-CH), 128.7 (Ar-CH), 131.8 (Ar-C), 132.1 (Ar-C), 133.8 (Ar-C) and 168.4 (C=O); *m/z* (EI) 229 (M^+, 1.4 %) 199 (18), 184 (M - CO_2H, 100), 168 (8), 155 (35) and 127 (27); (HRMS: found M^+, 229.1109. $C_{14}H_{15}NO_2$ requires M, 229.1103).

Synthesis of theborane complex of N,N-dimethyl-2-naphthylmethylamine 12

2-Naphthoyl chloride (4.00 g, 20.98 mmol) was added portionwise to a biphasic mixture of dimethylamine hydrochloride (4.90 g, 60 mmol) and NaOH (3.40 g, 85 mmol) in H_2O (40 ml) and Et_2O (40 ml) at 0 °C. After stirring vigorously for 2 min EtOAc (20 ml) was added and stirring continued for 1 h at which time TLC (20 % EtOAc in Et_2O) indicated complete consumption of starting material. Thus the phases were separated and the organic layer washed with 1 M HCl solution (2 x 50 ml), 2 M NaOH solution (50 ml), brine (50 ml) before being dried over $MgSO_4$ and concentrated *in vacuo* to yield the desired amide

as a white solid (4.18 g, 100 %), m.p. 82-83 °C (lit. m.p. 87-88 °C)[20]; υ_{max} ($CHCl_3$)/cm^{-1} 2994, 2934, 1622 (C=O), 1574, 1496, 1399, 1130, 1077 and 863; δ_H (400 MHz, $CDCl_3$) 3.03 (3H, s, NC*H*$_3$), 3.16 (3H, s, NC*H*$_3$), 7.52 (3H, m, Ar*H*), 7.86 (3H, m, Ar*H*) and 7.91 (1H, s, C(1)*H*); δ_C (68 MHz, $CDCl_3$) 35.1 (CH_3), 39.3 (CH_3), 124.1 (Ar-CH), 126.3 (Ar-CH), 126.5 (Ar-CH), 126.7 (Ar-CH), 127.5 (Ar-CH), 127.9 (Ar-CH), 128.1 (Ar-CH), 132.3 (Ar-C), 133.3 (Ar-C), 133.4 (Ar-C) and 171.2 (C=O); *m/z* (EI) 199 (M^+, 48 %), 155 (M - $N(CH_3)_2$, 100), 127 (M - $CON(CH_3)_2$, 78), 101 (5) and 77 (7), (HRMS: found M^+, 199.1001. $C_{13}H_{13}NO$ requires M, 199.0997).

BH_3·dimethylsulfide complex (0.81 ml, 8.53 mmol) was added dropwise to a stirred solution of amide prepared as described above (1.00 g, 5.02 mmol) in THF (20 ml) at O °C under a N_2 atmosphere. The solution was stirred for 10 min before removing the ice bath and stirring overnight. The solution was then partitioned between saturated NH_4Cl solution (50 ml) and Et_2O (50 ml).The organic layer was separated and the aqueous layer extracted further with diethyl ether (2 x 50 ml). The organics were then combined, washed with saturated brine (50 ml), dried over $MgSO_4$ and concentrated under reduced pressure to yield crude product which was recrystallised from EtOAc providing complex **12** as a white solid (0.95 g, 95 %), m.p. 145-6 °C; υ_{max} ($CHCl_3$)/cm^{-1} 2951, 2387 (B-H), 2321 (B-H), 2272 (B-H), 1465, 1300, 1165 and 1134; δ_H (400 MHz, $CDCl_3$) 0.9-2.7 (3H, v. br., B*H*$_3$), 2.56 (6H, s, N(C*H*$_3$)$_2$), 4.15 (2H, s, ArC*H*$_2$), 7.43 (1H, dd, *J* 8.4 and 1.6, Ar*H*), 7.55 (2H, m, Ar*H*), 7.80 (1H, s, C(1)*H*) and 7.86 (3H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 49.7 (2 x CH_3), 67.5 (CH_2), 126.5 (Ar-CH), 126.8 (Ar-CH), 127.6 (Ar-CH), 128.0 (2 x Ar-CH), 129.2 (Ar-CH), 131.8 (Ar-CH), 128.6 (C(2)), 132.8 (Ar-C) and 133.2 (Ar-C); *m/z* (CI) 198 (M^+ - 1, 5 %), 186 (53), 171 (40), 157 (30), 142 (100), 129 (22) and 74 (45); (HRMS: found M^+ - H, 198.1454. $C_{13}H_{18}BN$ - H requires M, 198.1457).

General procedure for substitution–decomplexation of ***12*** *to give amines* ***14****: methylation to give* ***14*** *(R = Me)*[21]

A solution of ^{n}BuLi (0.412 ml of a 1.6 M solution in hexanes, 0.66 mmol) was added dropwise to a solution of complex **12** (66 mg, 0.33 mmol) in THF (3.5 ml) at -78 °C under a N_2 atmosphere. The solution was then warmed to 0 °C for 1h, before recooling to -78 °C and addition of methyl iodide (0.10 ml, 1.7 mmol) as a single portion. After 2 min the deep brown colouration had dissipated so the cooling bath was removed and the reaction mixture allowed to warm to room temperature for 30 min before the addition of saturated $NaHCO_3$ solution (10 ml). The phases were separated and the aqueous layer extracted further with

diethyl ether (2 x 10 ml). The combined organic extracts were then washed with saturated brine (*ca.* 20 ml), dried over $MgSO_4$ and concentrated under reduced pressure to yield a colourless oil. This oil was diluted in EtOH (10 ml) and heated at reflux overnight before the reaction mixture was concentrated under reduced pressure and purified on silica gel (EtOAc then 2 % MeOH in EtOAc as eluents) to yield **14** (E = Me) a colourless oil (44 mg, 66 %), υ_{max} ($CHCl_3$)/cm^{-1} 2937, 2862, 2822, 2778, 1457, 1372, 1309, 944, 895 and 860; δ_H (400 MHz, $CDCl_3$) 1.45 (3H, d, *J* 6.5, CHC*H*$_3$), 2.24 (6H, s, N(C*H*$_3$)$_2$), 3.38 (1H, q, *J* 6.5, C*H*CH$_3$), 7.46 (3H, m, Ar*H*), 7.70 (1H, s, C(1)*H*) and 7.80 (3H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 20.3 (CH_3), 43.5 (2 x NCH_3), 66.2 (CH), 125.5 (Ar-CH), 125.8 (Ar-CH), 125.9 (Ar-CH), 126.0 (Ar-CH), 127.6 (Ar-CH), 127.8 (Ar-CH), 128.0 (Ar-CH), 132.76 (Ar-C), 133.4 (Ar-C) and 141.9 (Ar-C); *m/z* (EI) 199 (M^+, 14 %), 184 (M - CH_3, 100), 168 (4), 155 (26), 141 (9), 128 (6) and 72 (14); (HRMS: found M^+, 199.1362. $C_{14}H_{17}N$ requires M, 199.1361).

Silylation of ***12*** *to give* ***14*** *(E = $SiMe_3$)*

The general substitution–decomplexation procedure was followed using complex **12** (199 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and $(CH_3)_3SiCl$ (0.63 ml, 5 mmol). Standard decomplexation and purification on silica gel (25 % EtOAc in petroleum ether as eluent) gave **14** (E = $SiMe_3$) as a yellow oil (161 mg, 63 %), υ_{max} ($CHCl_3$)/cm^{-1} 3058, 2952, 2863, 2820, 2772, 1507, 1251, 1037 and 836; δ_H (250 MHz, $CDCl_3$) 0.01 (9H, s, Si(C*H*$_3$)$_3$), 2.34 (6H, s, N(C*H*$_3$)$_2$), 2.84 (1H, s, ArC*H*), 7.36-7.49 (3H, m, Ar*H*), 7.61 (1H, s, C(1)*H*) and 7.74-7.82 (3H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) -1.1 (Si(CH_3)$_3$), 47.2 (2 x NCH_3), 68.2 (CH), 124.9 (Ar-CH), 125.7 (Ar-CH), 125.8 (Ar-CH), 127.0 (Ar-CH), 127.5 (2 x Ar-CH), 127.6 (Ar-CH),; *m/z* (EI) 257 (M^+, 3 %), 242 (2), 184 (M - Si(CH_3)$_3$, 100), 153 (2) and 84 (15); (HRMS: found M^+, 257.1592. $C_{16}H_{23}NSi$ requires M, 257.1600).

Reaction of ***12*** *with benzaldehyde to give* ***14*** *[E = CH(OH)Ph]*

The general substitution–decomplexation procedure was followed using complex **12** (100 mg, 0.5 mmol) in THF (5 ml), ^{n}BuLi (0.63 ml of a 1.6 M solution in hexanes, 1 mmol) and benzaldehyde (0.26 ml, 2.5 mmol). Standard decomplexation and purification on silica gel (50 %, 66 % EtOAc in petroleum ether then EtOAc as eluents) gave firstly the minor erythro isomer of **14** [E = CH(OH)Ph] as a yellow oil (13 mg, 9 %), υ_{max} ($CHCl_3$)/cm^{-1} 3303 (O-H), 3062, 2944, 2872, 2835, 2791, 1410, 1202 and 1051; δ_H (400 MHz, $CDCl_3$) 2.29 (6H, s, N(C*H*$_3$)$_2$), 3.72 (1H, d, *J* 10.3, C*H*N(CH_3)$_2$), 5.13 (1H, d, *J* 10.2, C*H*OH), 7.05-7.46

(8H, m, Ar*H*), 7.51 (1H, s, C(1)*H*) and 7.75 (3H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 40.9 (2 x CH_3), 71.0 (CH), 75.7 (CH), 125.9-127.9 (10 x Ar-CH), 129.5 (Ar-C), 130.1 (Ar-C), 132.8 (Ar-C) and 141.5 (Ar-C); *m/z* (CI) 292 (M^+ + 1, 34 %), 274 (M - OH, 11), 247 (M - $N(CH_3)_2$, 22), 214 (5), 184 (100), 170 (5), 141 (6) and 107 (15); (HRMS: found M^+ + H, 292.1680. $C_{20}H_{21}NO$ + H requires M, 292.1701), followed by mixed fractions of the two stereoisomers (45 mg, 31 %) followed by erythro **14** [E = CH(OH)Ph] as a yellow oil (57 mg, 39 %, 79 % overall), υ_{max} ($CHCl_3$)/cm^{-1} 3420 (O-H), 3062, 3029, 3001, 2958, 2872, 2828, 2783, 1408, 1058 and 1040; δ_H (400 MHz, $CDCl_3$) 2.37 (6H, s, $N(CH_3)_2$), 3.37 (1H, d, *J* 4.1, $CHN(CH_3)_2$), 5.38 (1H, d, *J* 4.1, CHOH), 7.04 (5H, m, Ar*H*), 7.22 (1H, d, *J* 8.5, Ar*H*) and 7.35-7.75 (6H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 44.2 (2 x CH_3), 72.7 (CH), 77.6 (CH), 125.5-128.6 (10 x Ar-CH), 132.72 (Ar-C), 132.8 (Ar-C), 134.3 (Ar-C) and 141.1 (Ar-C); *m/z* (CI) 292 (M^+ + 1, 66 %), 274 (M - OH, 39), 247 (M - $N(CH_3)_2$, 40), 235 (7), 213 (7), 184 (100), 135 (39), 105 (55); (HRMS: found M^+ + H, 292.1695. $C_{20}H_{21}NO$ + H requires M, 292.1701).

Reaction of 12 with CO_2 to give 14 (E = CO_2H)

The general substitution–decomplexation procedure was followed using complex **12** (100 mg, 0.5 mmol) in THF (5 ml), ^{n}BuLi (0.625 ml of a 1.6 M solution in hexanes, 1 mmol) and CO_2 gas (bubbled through the reaction mixture at -78 °C for 10 min). Standard decomplexation gave a solid which was triturated from Et_2O to yield the amino acid **14** (E = CO_2H) as a white solid (82.5 mg, 72 %), m.p. 206-8 °C; υ_{max} (Nujol mull)/cm^{-1} 3372 (O-H), 2920, 2853, 1620 (C=O), 1309, 1153 and 816; δ_H (270 MHz, $CDCl_3$) 2.58 (6H, s, $N(CH_3)_2$), 4.43 (1H, s, ArC*H*), 7.65 (3H, m, Ar*H*) and 7.99 (4H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 42.1 (2 x CH_3), 74.8 (CH), 126.0 (Ar-CH), 126.5 (2 x Ar-CH), 127.6 (Ar-CH), 127.9 (Ar-CH), 128.1 (Ar-CH), 128.4 (Ar-CH), 132.6 (Ar-C), 132.7 (Ar-C), 132.9 (Ar-C) and 168.4 (C=O); *m/z* (EI) 229 (M^+, 0.9 %), 184 (M - CO_2H, 100), 168 (7), 141 (5) and 128 (4); (HRMS: found M^+, 229.1103. $C_{14}H_{15}NO_2$ requires M, 229.1103).

Reaction of 12 with benzophenone to give 14 [E = C(OH)Ph_2]

The general substitution–decomplexation procedure was followed using complex **12** (100 mg, 0.5 mmol) in THF (5 ml), ^{n}BuLi (0.63 ml of a 1.6 M solution in hexanes, 1 mmol) and benzophenone (0.46 g, 2.5 mmol). Standard decomplexation and purification on silica gel (10 % Et_2O in petroleum ether as eluent) gave **14** [E = C(OH)Ph_2] as a white solid (139 mg, 75 %), m.p. 80-82 °C; υ_{max} ($CHCl_3$)/cm^{-1} 3284 (O-H), 3062, 3033, 2953, 2873, 2834, 2790, 1596, 1318, 1187 and 1032; δ_H (250 MHz, $CDCl_3$) 2.06 (6H, s,

N(CH_3)$_2$), 5.58 (1H, s, C*H*N(CH_3)$_2$), 5.84 (1H, br. s, O*H*), 6.75-6.88 (3H, m, Ar*H*), 7.10-7.61 (9H, m, Ar*H*), 7.78-7.83 (4H, m, Ar*H*), 8.24 (1H, d, *J* 8.5, Ar*H*); δ_C (68 MHz, $CDCl_3$) 45.4 (2 x CH_3), 69.7 (CH), 79.3 (C), 123.2-129.6 (17 x Ar-CH), 133.5 (Ar-C), 133.6 (Ar-C), 134.5 (Ar-C), 146.3 (Ar-C) and 150.0 (Ar-C); *m/z* (EI) 368 (M^+ + 1, 3 %), 184 (100), 168 (16), 105 (15); (HRMS: found M^+ + H, 368.2044. $C_{26}H_{25}NO$ + H requires M, 368.2014).

General procedure for the substitution–decomplexation of ***12*** *with enolizable carbonyl electrophiles: preparation of* ***14*** *[E = CH(OH)cy-hex]*

A solution of ^{n}BuLi (0.63 ml of a 1.6 M solution in hexanes, 1 mmol) was added dropwise to a solution of complex **12** (100 mg, 0.5 mmol) in THF (5 ml) at -78 °C under a N_2 atmosphere. The solution was then warmed to 0 °C for 1h, before dropwise addition of the brown reaction mixture to a solution of cyclohexane carboxaldehyde (1.21 ml, 10 mmol) in THF (5 ml) at -78 °C (duration *ca.* 6 min). Stirring was then continued for 5 min before the addition of saturated $NaHCO_3$ solution (10 ml). The phases were separated and the aqueous layer extracted further with diethyl ether (2 x 10 ml). The combined organic extracts were then washed with saturated brine (*ca.* 20 ml), dried over $MgSO_4$ and concentrated under reduced pressure. The resulting oil was diluted in EtOH (10 ml) and heated at reflux overnight before the reaction mixture was concentrated under reduced pressure yielding a mixture of diastereomers (1.2 : 1). Purification on silica gel (50 % EtOAc in petroleum ether, EtOAc then 1 % MeOH in EtOAc as eluents) gave firstly the minor (threo) diastereomer of **14** [E = CH(OH)cy-hex] as a colourless oil (40.3 mg, 27 %), υ_{max} ($CHCl_3$)/cm^{-1} 3360 (O-H), 2932, 2855, 2790, 1415 and 1041; δ_H (400 MHz, $CDCl_3$) 1.12-1.80 (11H, m, C_5H_{11}), 2.20 (6H, s, N(CH_3)$_2$), 3.64 (1H, d, *J* 10.5, C*H*N(CH_3)$_2$), 4.01 (1H, dd, *J* 10.6 and 3.1, C*H*OH), 7.27 (1H, dd, *J* 8.4 and 1.6, C(3)*H*), 7.51 (2H, m, Ar*H*), 7.57 (1H, s, C(1)*H*) and 7.84 (3H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 25.1 (CH_2), 26.1 (CH_2), 26.4 (CH_2), 26.7 (CH_2), 31.1 (CH_2), 39.0 (CH), 40.7 (2 x CH_3), 70.6 (CH), 71.6 (CH), 126.0-129.0 (7 x Ar-CH), 131.0 (Ar-C), 132.9 (Ar-C) and 133.0 (Ar-C); *m/z* (CI) 298 (M^+ + 1, 70 %), 280 (M - OH, 6), 253 (M - N(CH_3)$_2$, 17), 235 (12), 214 (4), 200 (13), 184 (100), 139 (15); (HRMS: found M^+ + H, 298.2197. $C_{20}H_{27}NO$ + H requires M, 298.2171), then mixed fractions containing both diastereomers (20.4 mg, 14 %) followed by the major (erythro) diastereomer of **14** [E = CH(OH)cy-hex] as a colourless oil (35 mg, 24 %, 65 % overall), υ_{max} ($CHCl_3$)/cm^{-1} 3399 (O-H), 2932, 2854, 2783, 1508, 1411, 1248 and 1041; δ_H (400 MHz, $CDCl_3$) 0.97-1.72 (11H, cm, C_6H_{11}), 2.29 (6H, s, N(CH_3)$_2$), 3.38 (1H, d, *J* 3.8, C*H*N(CH_3)$_2$), 3.89 (1H, m, C*H*OH), 4.37 (1H, br. s., D_2O exchangable, O*H*) and 7.25-7.85 (7H, m,

Ar*H*); δ_C (68 MHz, $CDCl_3$) 25.5 (2 x CH_2), 26.4 (CH_2), 28.8 (CH_2), 29.4 (CH_2), 39.8 (CH), 44.0 (2 x CH_3), 73.2 (CH), 74.2 (CH), 125.9 (2 x Ar-CH), 127.6 (Ar-CH), 127.7 (2 x Ar-CH), 128.0 (Ar-CH), 129.0 (Ar-CH), 133.0 (2 x Ar-C) and 134.7 (Ar-C); *m/z* (CI) 298 (M^+ + 1, 87 %) 280 (M - OH, 31), 253 (M - $N(CH_3)_2$, 20), 235 (11), 214 (9), 184 (100), 141 (29), 129 (31) and 111 (15); (HRMS: found M^+ + H, 298.2168. $C_{20}H_{27}NO$ + H requires M, 298.2171).

Reaction of 12 with isobutyraldehyde to give 14 [E = CH(OH)^{i}Pr]

The general inverse addition procedure for the substitution–decomplexation was followed using complex **12** (100 mg, 0.5 mmol) in THF (5 ml), BuLi (0.63 ml of a 1.6 M solution in hexanes, 1 mmol) and isobutyraldehyde (0.91 ml, 10 mmol) in THF (5 ml). Standard decomplexation gave a mixture of diastereomers (1.2 : 1). Purification on silica gel (50 % EtOAc in petroleum ether then EtOAc as eluents) recovered firstly the minor (threo) diastereomer of **14** [E = CH(OH)^{i}Pr] as a colourless oil (42 mg, 33 %), υ_{max} ($CHCl_3$)/cm^{-1} 3361 (O-H), 3059, 2962, 2873, 2834, 2789, 1413, 1275, 1124 and 1005; δ_H (400 MHz, $CDCl_3$) 0.79 (3H, d, *J* 6.7, $CHCH_3$), 1.01 (3H, d, *J* 6.7, $CHCH_3$), 1.45 (1H, d of septets, *J* 2.0 and 6.7, $CH(CH_3)_2$), 2.21 (6H, s, $N(CH_3)_2$), 3.56 (1H, d, *J* 10.5, ArC*H*), 4.06 (1H, dd, *J* 10.5 and 2.0, C*H*OH), 7.26 (1H, d, *J* 9.7, C(3)*H*), 7.49 (2H, m, Ar*H*), 7.58 (1H, s, C(1)*H*) and 7.81-7.86 (3H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 14.4 (CH_3), 20.9 (CH_3), 28.9 (CH), 40.8 (2 x NCH_3), 71.6 (CH), 71.7 (CH) 126.0 (Ar-CH), 126.1 (Ar-CH), 127.4 (2 x Ar-CH), 127.6 (Ar-CH), 127.9 (Ar-CH), 129.1 (Ar-CH), 130.9 (Ar-C), 132.9 (Ar-C) and 133.0 (Ar-C); *m/z* (CI) 258 (M^++1, 100 %), 241 (M - OH, 8), 213 (M - $N(CH_3)_2$, 26), 184 (59) and 141 (26); (HRMS: found M^+ + H, 258.1844. $C_{17}H_{23}NO$ + H requires M, 258.1831), then mixed fractions containing both diastereomers (28 mg, 22 %) followed by the major (erythro) diastereomer of **14** [E = CH(OH)^{i}Pr] as a colourless oil (25 mg, 20 %, 75 % overall), υ_{max} ($CHCl_3$)/cm^{-1} 3408 (O-H), 3059, 2960, 2872, 2828, 2783, 1410, 1056 and 1041; δ_H (400 MHz, $CDCl_3$) 0.82 (3H, d, *J* 6.6, $CHCH_3$), 0.95 (3H, d, *J* 6.5, $CHCH_3$), 1.16-1.30 (1H, m, $CH(CH_3)_2$), 2.25 (6H, s, $N(CH_3)_2$), 3.25 (1H, d, *J* 4.2, ArC*H*), 3.75 (1H, dd, *J* 8.8 and 4.2, C*H*OH), 7.48 (2H, m, Ar*H*), 7.57 (1H, *J* 8.5 and 1.7, C(3)*H*) and 7.73-7.84 (4H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 18.5 (CH_3), 19.3 (CH_3), 30.4 (CH), 44.1 (2 x NCH_3), 73.5 (CH), 75.5 (CH), 125.8 (Ar-CH), 125.9 (Ar-CH), 127.5 (Ar-CH), 127.6 (Ar-CH), 127.7 (Ar-CH), 127.9 (Ar-CH), 128.8 (Ar-CH), 132.92 (Ar-C), 133.0 (Ar-C), 135.5 (Ar-C); *m/z* (EI) 258 (M^++ 1, 39 %), 240 (M - OH, 40), 213 (M - $N(CH_3)_2$, 34), 200 (16), 184 (100), 141 (44); (HRMS: found M^+ + H, 258.1875. $C_{17}H_{23}NO$ + H requires M, 258.1858).

Preparation of 2-Methyl-1,2,3,4-tetrahydroisoquinoline–borane complex ***16***

(i) 2-Methyl-1,2,3,4-tetrahydroisoquinoline[22]

Formic acid (0.76 ml, 20 mmol) and 37 % aqueous formaldehyde (0.83 ml, 11 mmol) were added to 1,2,3,4-tetrahydroisoquinoline (1.25 ml, 10 mmol) at 0 °C. The resulting gel was heated at 80 °C for 24 h before recooling to 0 °C and cautious addition of 6N HCl solution (10 ml). The mixture was extracted with Et_2O (3 x 20 ml) before basifying the aqueous phase to pH >10 with 2N NaOH solution and re-extracting with Et_2O (3 x 20 ml). The latter organic extracts were then combined, washed with brine, dried ($MgSO_4$) and concentrated *in vacuo* to yield the crude product as a yellow oil. Purification by silica gel chromatography (10 % MeOH in EtOAc as eluent) gave the desired *N*-methylated tetrahydroisoquinoline as a colourless oil (1.33 g, 91 %).

(ii) 2-Methyl-1,2,3,4-tetrahydroisoquinoline–borane complex ***16***

BH_3·THF complex (15 ml of a 1M solution in THF, 15 mmol) was added dropwise to a stirred solution of the tetrahydroisoquinoline prepared as described above (2.11 g, 14.4 mmol) in THF (10 ml) at 0 °C under a N_2 atmosphere. The solution was stirred for 15 min at which time TLC (50 % Et_2O in petroleum ether) showed complete complexation of starting material. Thus the solvent was removed under reduced pressure and the residue partitioned between EtOAc (30 ml) and 2N HCl solution (30 ml). The organics were separated and washed further with saturated brine (30 ml), dried ($MgSO_4$) and concentrated under reduced pressure. The resulting white solid was then recrystallised from cyclohexane–dichloromethane (50 : 1) to yield the title borane complex as a white crystalline solid (1.99 g, 86 %), m.p. 92-94 °C, (Found: C, 74.39; H, 10.19; N, 8.37. $C_{10}H_{16}BN$ requires; C, 74.57; H, 10.01; N, 8.70 %); υ_{max} ($CHCl_3$)/cm^{-1} 2416 (B-H), 2368 (B-H), 2272 (B-H), 1455, 1161 and 975; δ_H (250 MHz, $CDCl_3$) 1.2-2.25 (3H, v. br., B*H*$_3$), 2.63 (3H, s, NC*H*$_3$), 3.05 (2H, m, 4-H), 3.22 (2H, m, 3-H), 3.85 (1H, d, *J* 16.0, 1-H), 4.24 (1H, d, *J* 16.0, 1-H), 7.03 (1H, d, *J* 6.8, Ar*H*) and 7.21 (3H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 24.2 ($C(4)H_2$), 26.9 (CH_3), 56.4 ($C(3)H_2$), 61.3 ($C(1)H_2$), 126.7 (Ar-CH), 126.8 (Ar-CH), 127.3 (Ar-CH), 128.6 (Ar-CH), 130.1 (Ar-C) and 130.6 (Ar-C); *m/z* (FAB) 160 (M^+ - 1 59 %), 136 (62), 107 (19), 91 (14) and 77 (16), (HRMS: found M^+ - 1, 160.1302. $C_{11}H_{15}N$ - H requires M, 160.1298).

Alternatively the complex **16** was prepared by addition of BH_3·dimethylsulfide complex (1.93 ml, 20.4 mmol) dropwise to a stirred solution of starting tetrahydroisoquinoline (3.0 g, 20.4 mmol) in anhydrous hexane (50 ml) at 0 °C. The resulting suspension was stirred for 24 h, filtered and dried *in vacuo* to yield **16** as a white solid (3.07 g, 94 %). All data were consistent with those described above.

*Silylation of tetrahydroisoquinoline–borane complex **16** to give **17** (E = SiMe$_3$)*[1a]

The general procedure for the substitution–decomplexation of complex **2** to give **7** was followed using complex **16** (161 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and $(CH_3)_3SiCl$ (0.63 ml, 5 mmol). Standard decomplexation and purification on silica gel ($CHCl_3$ as eluent) gave **17** (E = $SiMe_3$) as a colourless oil (140 mg, 64 %), υ_{max} ($CHCl_3$)/cm^{-1} 3212, 2946, 2845, 2789, 1643, 1455, 1096, 908 and 864; δ_H (250 MHz, $CDCl_3$) 0.32 (9H, s, Si(C*H*$_3$)$_3$), 2.49 (3H, s, NC*H*$_3$), 2.57-2.91 (3H, m, ArC*H*$_2$C*H*HN), 3.15 (1H, m, ArCH$_2$CH*H*N), 3.20 (1H, s, ArC*H*N) 6.91 (1H, d, *J* 7.0, Ar*H*) and 7.00-7.14 (3H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) -2.1 (Si(CH_3)$_3$), 26.7 (C(4)H$_2$), 45.5 (NCH_3), 50.5 (C(3)H$_2$), 58.6 (CH), 124.1 (Ar-CH), 125.3 (Ar-CH), 126.1 (Ar-CH), 128.5 (Ar-CH), 133.8 (Ar-C) and 137.4 (Ar-C); *m/z* (EI) 219 (M$^+$, 3 %), 218 (6), 172 (11), 161 (55), 146 (M - Si(C*H*$_3$)$_3$, 26), 118 (100), 104 (10), 90 (55), 77 (12) and 72 (21), (HRMS: found M$^+$, 219.1422. $C_{13}H_{21}NOSi$ requires M, 219.1443).

*Methylation of tetrahydroisoquinoline–borane complex **16** to give **17** (E = Me)*[23]

The general procedure for the substitution–decomplexation of complex **2** to give **7** was followed using complex **16** (161 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and methyl iodide (0.31 ml, 5 mmol). Standard decomplexation and purification on silica gel (EtOAc, 5 % then 10 % MeOH in EtOAc as eluents) gave **17** (E = Me) as a yellow oil (136 mg, 79 %), υ_{max} ($CHCl_3$)/cm^{-1} 3206, 2913, 2849, 2799, 1463, 1370, 1104 and 908; δ_H (250 MHz, $CDCl_3$) 1.37 (3H, d, *J* 6.6, CHC*H*$_3$), 2.46 (3H, s, NC*H*$_3$), 2.61 (1H, ddd, *J* 11.8, 7.2 and 5.3, ArC*H*HCH$_2$N), 2.84 (2H, m, ArCH*H*C*H*HN), 3.01 (1H, ddd, *J* 11.8, 5.8 and 5.8, ArCH$_2$CH*H*N), 3.59 (1H, q, *J* 6.6, ArC*H*N) and 7.04-7.14 (4H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 19.5 (CH_3), 28.0 (C(4)H$_2$), 42.9 (NCH_3), 48.9 (C(3)H$_2$), 58.9 (CH), 125.6 (Ar-CH), 125.6 (Ar-CH), 126.7 (Ar-CH), 128.5 (Ar-CH), 133.7 (Ar-C) and 139.6 (Ar-C); *m/z* (EI) 160 (M$^+$ - 1, 6 %), 159 (7), 146 (M - CH_3, 100), 131 (9), 115 (13), 91 (6) and 77 (6); (HRMS found M$^+$ - H, 160.1080. $C_{11}H_{15}N$ - H requires M, 160.1126).

*Reaction of tetrahydroisoquinoline–borane complex **16** with PhCHO to give **17** [E = CH(OH)Ph]*[1a]

The general procedure for the substitution–decomplexation of **2** to give **7** was followed using complex **16** (161 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and benzaldehyde (0.51 ml, 5 mmol). Standard decomplexation gave a mixture of diastereomers (8 : 1).

Purification on silica gel ($CHCl_3$, 1 % and then 5 % MeOH in $CHCl_3$ as eluents) recovered firstly the major (erythro) diastereomer of **17** [E = CH(OH)Ph] as a white solid (107 mg, 42 %), m.p. 101-103 °C (lit.[1a], m.p. 103-104 °C); υ_{max} ($CHCl_3$)/cm^{-1} 3315, 2856, 2805, 1604, 1453, 1378 and 1099; δ_H (250 MHz, $CDCl_3$) 2.53 (1H, dt, *J* 11.4 and 6.1, $ArCH_2CHHN$), 2.60 (3H, s, NCH_3), 2.65 (2H, t, *J* 5.6, $ArCH_2CH_2N$), 2.92 (1H, dt, *J* 11.5 and 5.1, $ArCH_2CHHN$), 3.83 (1H, d, *J* 4.0, O*H*), 5.05 (1H, d, *J* 4.0, C*H*NMe), 6.35 (1H, d, *J* 7.7, C*H*OH), 6.88 (1H, t, *J* 7.0, Ar*H*), 6.90-7.09 (5H, m, Ar*H*) and 7.18-7.22 (3H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 27.7 ($C(4)H_2$), 44.1 (CH_3), 49.7 ($C(3)H_2$), 69.9 (CH), 74.6 (CH), 124.7 (Ar-CH), 126.2 (Ar-CH), 126.4 (Ar-CH), 126.8 (Ar-CH), 127.5 (Ar-CH), 128.6 (Ar-CH), 129.9 (Ar-CH), 132.5 (Ar-C), 136.6 (Ar-C) and 141.2 (Ar-C); *m/z* (FAB) 254 (M^+ + H, 61 %), 236 (M - OH, 16), 146 (100), 132 (6), 117 (6), 105 (5), 91 (5) and 77 (4), (HRMS: found M^+ + H, 254. 1536. $C_{17}H_{19}NO$ + H requires M, 254.1545), then mixed fractions containing both diastereomers (28 mg, 11 %) followed by the minor diastereomer of **17** [E = CH(OH)Ph] as a white solid (13 mg, 5 %, 58 % overall), m.p. 91-93 °C; υ_{max} ($CHCl_3$)/cm^{-1} 3272, 2946, 2856, 2810, 1603, 1454, 1342, 1103 and 968; δ_H (250 MHz, $CDCl_3$) 2.55 (3H, s, NCH_3), 2.63 (1H, ddd, *J* 17.2, 5.1and 2.8 $ArCHHCH_2N$), 2.90 (1H, ddd, *J* 13.5, 6.2 and 2.8, $ArCH_2CHHN$), 3.05 (1H, ddd, *J* 17.2, 11.2 and 6.2, $ArCHHCH_2N$), 3.40 (1H, ddd, *J* 13.5, 11.2 and 5.1, $ArCH_2CHHN$), 3.50 (1H, d, *J* 8.9, O*H*), 4.41 (1H, d, *J* 8.9, C*H*NMe), 5.94 (1H, d, *J* 7.6, C*H*OH), 6.80 (1H, m, Ar*H*), 7.09 (2H, m, Ar*H*) and 7.29 (7H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 23.0 ($C(4)H_2$), 42.2 (CH_3), 44.7 ($C(3)H_2$), 69.8 (CH), 75.7 (CH), 124.9 (Ar-CH), 126.7 (Ar-CH), 127.8 (Ar-CH), 128.0 (Ar-CH), 128.1 (Ar-CH), 128.5 (Ar-CH), 129.8 (Ar-CH), 132.0 (Ar-C), 134.1 (Ar-C) and 141.9 (Ar-C); *m/z* (EI) 253 (M^+, 6 %), 252 (22) 162 (9), 146 (100), 117 (18), 105 (33), 91 (23) and 77 (10), (HRMS: found M^+, 253.1435. $C_{17}H_{19}NO$ requires M, 253.1467).

*Reaction of tetrahydroisoquinoline–borane complex **16** with CO_2 to give **17** (E = CO_2H)*

The general substitution–decomplexation procedure of **2** to give **7** was followed using complex **16** (160 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and CO_2 gas (bubbled through the reaction mixture at -78 °C for 15 min). Standard decomplexation gave a solid which was triturated from Et_2O to yield the amino acid **17** (E = CO_2H) as a white solid (106 mg, 55 %), m.p. 189-93 °C; υ_{max} (Nujol mull)/cm^{-1} 3468 (O-H), 2930, 2723, 1642 (C=O), 1489, 1392, 1336, 1161, 910, 765 and 736; δ_H (250 MHz, D6-DMSO) 2.70 (3H, s, NCH_3), 2.84-3.07 (3H, m, $NCHHCH_2$), 3.46 (1H, m, $NCHHCH_2$), 4.41 (1H, s, $CHCO_2H$), 7.13-7.24 (3H, m, Ar*H*) and 7.50 (1H, m, Ar*H*); δ_C (68 MHz, D6-DMSO) 25.8 ($C(4)H_2$), 42.3 (CH_3), 48.2 ($C(3)H_2$), 67.8 (C(1)H), 126.0 (Ar-CH), 126.8 (Ar-CH), 127.0 (Ar-

CH), 128.3 (Ar-CH), 131.0 (Ar-C), 131.7 (Ar-C) and 168.5 (C=O); *m/z* (FAB) 192 (M^+ + 1, 100 %), 146 (M - CO_2H, 56), 136 (19), 105 (6) and 91 (9). (HRMS: found M^+ + H, 192.1014. $C_{11}H_{13}NO_2$ + H requires M, 192.1025).

*Reaction of tetrahydroisoquinoline–borane complex **16** with $ClCO_2Me$ to give **17** (E = CO_2Me)*

The general substitution–decomplexation procedure of **2** to give **7** was followed using complex **16** (160 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and methyl chloroformate (0.39 ml, 5 mmol). Standard decomplexation and purification on silica gel (10 % Et_2O in petroleum ether as eluent) gave **17** (E = CO_2Me) as a colourless oil (129 mg, 63 %), υ_{max} ($CHCl_3$)/cm^{-1} 2952, 2858, 2801, 1732 (C=O), 1454 and 1294; δ_H (250 MHz, $CDCl_3$) 2.51 (3H, s, NC*H*$_3$), 2.66 (1H, ddd, *J* 11.5, 7.0 and 6.0, ArC*H*HCH$_2$), 2.87 (1H, ddd, *J* 16.4, 6.0 and 5.0, ArCH$_2$C*H*H), 3.01 (1H, ddd, *J* 16.4, 7.0 and 6.0, ArCH$_2$CH*H*), 3.29 (1H, ddd, *J* 11.3, 6.0 and 5.0, ArCH*H*CH$_2$), 3.75 (3H, s, COC*H*$_3$), 4.31 (1H, s, C*H*CO$_2$CH$_3$) and 7.10-7.23 (4H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 28.5 (C(4)H$_2$), 43.7 (NCH$_3$), 48.7 (C(3)H$_2$), 51.9 (CH$_3$), 67.8 (CH), 125.8 (Ar-CH), 126.2 (Ar-CH), 127.1 (Ar-CH), 129.0 (Ar-CH), 131.5 (Ar-C), 134.2 (Ar-C), 172.8 (C=O); *m/z* (FAB) 206 (M^+ + H, 38 %), 146 (M - CO_2CH_3, 100), 135 (39), 123 (19), 109 (32), 95 (53) and 55 (100); (HRMS: found M^+ + H, 206.1181. $C_{12}H_{15}NO_2$ + H requires M, 206.1183).

*Allylation of tetrahydroisoquinoline–borane complex **16** to give **17** (E = allyl)*[24]

The general substitution–decomplexation procedure of **2** to give **7** was followed using complex **16** (160 mg, 1 mmol) in THF (10 ml), BuLi (1.25 ml of a 1.6 M solution in hexanes, 2 mmol) and allyl bromide (0.43 ml, 5 mmol). Standard decomplexation and purification on silica gel (25 % EtOAc in petroleum ether as eluent) gave **17** (E = allyl) as a colourless oil (111 mg, 59 %), υ_{max} ($CHCl_3$)/cm^{-1} 2937, 2851, 2796, 1639, 1453, 1372, 1096 and 914; δ_H (250 MHz, $CDCl_3$) 2.48 (3H, s, NC*H*$_3$), 2.55-2.73 (3H, m, NC*H*HCH$_2$ and C*H*$_2$CH=CH$_2$), 2.81 (2H, dd, *J* 5.9 and 5.9, NCH$_2$C*H*$_2$), 3.13 (1H, m, NCH*H*CH$_2$), 3.56 (1H, dd, *J* 5.5 and 5.5, ArC*H*)), 5.05 (2H, m, CH=C*H*$_2$), 5.78 (1H, dddd, *J* 17.1, 10.2, 6.7 and 6.7, C*H*=CH$_2$) and 7.07-7.15 (4H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 26.6 (C(4)H$_2$), 38.8 (CH$_2$), 42.8 (CH$_3$), 48.5 (C(3)H$_2$), 63.5 (C(1)H), 116.1 (CH$_2$), 125.6 (Ar-CH), 125.8 (Ar-CH), 127.2 (Ar-CH), 128.6 (Ar-CH), 134.7 (Ar-C), 135.9 (CH) and 137.6 (Ar-C); *m/z* (EI) 186 (M^+ - 1, 86 %) 175 (32), 162 (66), 147 (M - C_2H_5, 100), 131 (38) and 105 (17); (HRMS: found M^+ - H, 186.1284. $C_{13}H_{17}N$ - H requires M, 186.1282).

Preparation of 2-methylisoindoline-borane complex ***20***[25]

(i) N-methylphthalimide [26]

A solution of methylamine hydrochloride salt (18.2 g, 0.27 mol) in H_2O (50 ml) was added to a refluxing solution of phthalic anhydride (37.0 g, 0.25 mol) in glacial acetic acid (150 ml). Triethylamine (30.1 g, 0.30 mol) was then added cautiously and reflux maintained for 30 min at which time TLC (3 x 25 % Et_2O in petroleum ether) showed complete consumption of starting material. The reaction mixture was allowed to stir overnight before pouring the white suspension into H_2O (800 ml) and filtering to recover *N*-methylphthalimide as a white crystalline solid (27.6 g, 69 %), m.p. 132-134 °C (lit.[26], m.p. 130-132 °C); δ_H (400 MHz, $CDCl_3$) 3.19 (3H, s, NC*H*$_3$), 7.71 (2H, dd, *J* 5.4 and 3.0, Ar*H*) and 7.85 (2H, dd, *J* 5.4 and 3.0, Ar*H*)

(ii) 2-methylisoindoline–borane complex ***20***

BH_3·dimethylsulfide (18.0 ml, 190 mmol) was added dropwise to a stirred suspension of the phthalimide prepared as described above (12.4 g, 77 mmol) in THF (100 ml) at room temperature before heating the mixture at reflux for 1 h. Dimethyl sulfide was then removed by distillation at which time TLC (25 % Et_2O in petroleum ether) indicated remaining starting material. Reflux was maintained for a further 16 h before the reaction mixture was partitioned between EtOAc (100 ml) and saturated $NaHCO_3$ solution (100 ml). The organics were separated and the aqueous layer extracted further with EtOAc (2 x 100 ml). The organics were then combined, dried ($MgSO_4$) and concentrated *in vacuo* to yield a crude white solid which was recrystallised to analytical purity from petroleum ether–dichloromethane to yield complex **20** (10.4 g, 91 %), m.p. 102-103 °C; (Found: C, 73.40; H, 9.66; N, 9.24. $C_9H_{14}BN$ requires C, 73.52; H, 9.60; N, 9.53 %); υ_{max} ($CHCl_3$)/cm^{-1} 2995, 2945, 2862, 2351 (B-H), 2316 (B-H), 2270 (B-H), 1464, 1450, 1159, 962 and 889; δ_H (400 MHz, $CDCl_3$) 1.1-2.7 (3H, v. br., B*H*$_3$), 2.82 (3H, s, NC*H*$_3$), 4.08 (2H, d, *J* 14,.0 NC*H*H), 4.59 (2H, d, *J* 14,.0 NCH*H*) and 7.20-7.31 (4H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 51.9 (CH_3), 68.2 (2 x CH_2), 122.6 (2 x Ar-CH), 127.8 (2 x Ar-CH) and 136.3 (2 x Ar-C); *m/z* (EI) 146 (M^+ - 1, 21 %), 132 (M - BH_3, 24), 117 (M - BH_3 - CH_3, 4), 105 (100), 56 (64).

Substitution of isoindoline complex ***20*** *to give the diastereomeric complexes* ***21a*** *and* ***21b***

A solution of ^{n}BuLi (0.72 ml of a 1.4 M solution in hexanes, 1 mmol) was added dropwise to a solution of complex **20** (74 mg, 0.5 mmol) in THF (5 ml) at -78 °C under a N_2 atmosphere. The solution was

then allowed to warm to 0 °C over 1 h, before recooling to -78 °C and addition of iodomethane (0.17 ml, 2.5 mmol) as a single portion. After 10 min the cooling bath was removed and the reaction mixture allowed to warm to room temperature for 30 min before partitioning between Et_2O (10 ml) and saturated $NaHCO_3$ solution (5 ml). The phases were separated and the aqueous layer extracted further with Et_2O (2 x 10 ml). The combined organic extracts were then washed with saturated brine (*ca.* 20 ml), dried ($MgSO_4$) and concentrated under reduced pressure to yield a yellow oil. Purification of the crude reaction mixture by flash chromatography (10 then 25 % Et_2O in petroleum ether) gave **21a** as a white solid (51 mg, 63 %), m.p. 84 °C; υ_{max} ($CHCl_3$)/cm^{-1} 2996, 2944, 2858, 2356 (B-H), 2274 (B-H), 1463, 1452, 1349, 1162 and 890; δ_H (250 MHz, $CDCl_3$) 0.8-2.3 (3H, v. br., BH_3), 1.57 (3H, d, *J* 6.9, CHCH_3), 2.81 (3H, s, NCH_3), 4.02 (1H, d, *J* 14.3, ArC*H*H), 4.15 (1H, q, *J* 6.9, C*H*CH$_3$), 4.53 (1H, d, *J* 14.3, ArCH*H*) and 7.17-7.33 (4H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 17.1 (CH_3), 52.0 (NCH_3), 67.1 (CH_2), 72.31 (CH), 122.4 (Ar-CH), 122.6 (Ar-CH), 127.9 (2 x Ar-CH), 135.6 (Ar-C) and 141.9 (Ar-C); *m/z* (EI) 161 (M^+, 2 %), 160 (30), 146 (M - BH_3, 14), 132 (M - BH_3 - CH_3, 100), 117 (14), 105 (7), 91 (16) and 70 (19); (HRMS: found M^+, 161.1376. $C_{10}H_{16}BN$ requires M, 161.1376), followed by **21b** as a colourless oil (10 mg, 12 %, 75 % overall), υ_{max} ($CHCl_3$)/cm^{-1} 2945, 2860, 2358 (B-H), 2316 (B-H), 2272 (B-H), 1462, 1378, 1161, 990 and 908; δ_H (250 MHz, $CDCl_3$) 1.59 (3H, d, *J* 7.0, CHCH_3), 2.46 (3H, s, NCH_3), 4.00 (1H, d, *J* 14.9, ArC*H*H), 4.57 (1H, d, *J* 14.9, ArCH*H*), 4.61 (1H, q, *J* 6.7, C*H*CH$_3$) and 7.14-7.36 (4H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 12.5 (CH_3), 43.5 (NCH_3), 68.4 (CH_2), 70.4 (CH), 122.5 (Ar-CH), 122.7 (Ar-CH), 128.2 (2 x Ar-CH), 135.1 (Ar-C) and 141.4 (Ar-C); *m/z* (EI) 161 (M^+, 8 %), 160 (44), 146 (M - BH_3, 28), 144 (44), 132 (M - BH_3 - CH_3, 100), 117 (27), 115 (25) and 91 (28); (HRMS: found M^+, 161.1377. $C_{10}H_{16}BN$ requires M, 161.1376).

1,2-Dimethylisoindoline **22**[27]

Following substitution as described above using complex **20** (147 mg, 1 mmol) in THF (10 ml), ^{n}BuLi (1.43 ml of a 1.4 M solution in hexanes, 2 mmol) and iodomethane (0.32 ml, 5 mmol). The resulting oil was diluted in EtOH (20 ml) and heated at reflux overnight at which time TLC (25 % Et_2O in petroleum ether) indicated complete decomplexation of the starting material. The reaction mixture was therefore concentrated under reduced pressure and purified on silica gel (2 % then 5 % MeOH in $CHCl_3$ as eluent) to give **22** as a brown oil (93 mg, 63 %), υ_{max} ($CHCl_3$)/cm^{-1} 2969, 2929, 2845, 2781, 1602, 1456, 1354, 1059 and 908; δ_H (250 MHz, $CDCl_3$) 1.42 (3H, d, *J* 5.4, CHCH_3), 2.57 (3H, s, NCH_3), 3.63 (2H, m, ArC*H*H and C*H*CH$_3$), 4.23 (1H, d, *J* 11.5, ArCH*H*) and 7.11-7.23 (4H, m, Ar*H*); δ_C (68 MHz, $CDCl_3$) 18.2 (CH_3), 40.0

(NCH_3), 60.6 (CH_2), 65.3 (CH), 121.6 (Ar-CH), 121.9 (Ar-CH), 126.7 (2 x Ar-CH), 139.2 (Ar-C) and 144.8 (Ar-C); *m/z* (EI) 147 (M^+, 4 %), 146 (9), 132 (M - CH_3, 100) and 117 (8); (HRMS: found M^+, 147.1045. $C_{10}H_{13}N$ + H requires M, 147.1048).

References

1. a) Kessar, S. V.; Singh, P.; Vohra, R.; Kaur, N. P.; Singh, K. N. *J. Chem. Soc., Chem Commun.* **1991**, 568; b) Kessar, S. V.; Vohra, R.; Kaur, N. P.; Singh, K. N.; Singh, P.*J. Chem.Soc., Chem. Commun.* **1994**, 1327; c) Kessar, S. V.; Singh, P. *Chem. Rev.* **1997**, *97*, 721.
2. See also a) Vedejs, E.; Fields, S. C.; Lin, S.; Schrimpf, M. R. *J. Org. Chem.*, **1995**, *60*, 3028; b) Vedejs, E.; Fields, S. C.; Schrimpf, M. R. *J. Am. Chem. Soc.*, **1993**, *115*, 11612.
3. Ebden, M. R.; Simpkins, N. S.; Fox, D. N. A. *Tetrahedron Lett.* **1995**, *36*, 8697.
4. Ferey, V.; Toupet, L.; Le Gall, T.; Mioskowski, C. *Angew. Chem., Int. Ed. Engl.* **1996**, *35*, 430.
5. Ferey, V.; Vedrenne, P.; Toupet, L.; Le Gall, T.; Mioskowski, C. *J. Org. Chem.* **1996**, *61*, 7244.
6. (a) Puterbaugh, W. H.; Hauser, C. R. *J. Am. Chem. Soc.* **1963**, *85*, 2467. (b) Puterbaugh, W. H.; Hauser, C. R. *J. Org. Chem.* **1963**, *28*, 3465. See also (c) Katsoulos, G.; Schlosser, M. *Tetrahedron Lett.* **1993**, *34*, 6263.
7. Gay, R. L.; Hauser, C. R. *J. Am. Chem. Soc.* **1967**, *89*, 2297.
8. Munk, M. E.; Milahn, M. K.; Franklin, P. *J. Org. Chem.* **1968**, *33*, 3480.
9. Vedejs, E.; Kendall, J. T. *J. Am. Chem. Soc.* **1997**, *119*, 6941.
10. Blake, A. J.; Ebden, M. R.; Fox, D. N. A.; Li, W-S.; Simpkins, N. S.; *Synlett* **1998**, 189.
11. See for examples (a) Meyers, A. I.; Guiles, J.; Warmus, J. S.; Gonzalez, M. A. *Tetrahedron Lett.* **1991**, *32*, 5505. (b) Gawley, R. E.; Zhang, Q. *Tetrahedron* **1994**, *50*, 6077. (c) Elworthy, T. R.; Meyers, A. I. *Tetrahedron* **1994**, *50*, 6089.
12. Bourgeois, P.; Calas, R.; Duffaut N.; Dunogues, J. *J. Organomet. Chem.* **1971**, *32*, 79.
13. Ollis, W. D.; Ray, M.; Sutherland, I. O. *J. Chem. Soc., Perkin Trans I* **1983**, 1009.
14. Dunn, D. L.; Stevens, T. S. *J. Chem. Soc.* **1934**, 279.
15. Bumgardner, C. L. *J. Am. Chem. Soc.* **1963**, *85*, 73.
16. Hauser, C. R.; Stewart Jr., A. T., *J. Am. Chem. Soc.* **1955**, *77*, 1098.
17. Puterbaugh, W. H.; Hauser, C. R. *J. Am. Chem. Soc.* **1964**, *86*, 1108.
18. Knoop, F.; Oesterlin, H. *Z. Physiol. Chem.* **1927**, *120*, 186.
19. Braun, J. V. *Berichte.* **1904**, *37*, 2678.
20. Brown, H. C.; Tsukamoto, A. *J. Am. Chem. Soc.* **1964**, *86*, 1089.
21. Horner, L.; Simons, G. *Phosphorus and Sulfur, Int. Ed. Ger.* **1983**, *15*, 165.
22. Leonard, N. J.; Leubner, G. H. *J. Am. Chem. Soc.* **1949**, *71*, 3408.
23. Blagg, J.; Coote, S. J.; Davies, S. G. *J. Chem. Soc., Perkin Trans. 1* **1987**, 689.
24. de Costa, B. R.; Radesca, L. *Synthesis* **1992**, 887.
25. For the reduction of amides with BH_3·THF, omitting the isolation of the intermediate amine-borane complex, see (a) Brown, H. C.; Choi, Y. M.; Narasimhan, S. *J. Org. Chem.* **1982**, *47*, 3153. (b) Brown, H. C.; Heim, P. *J. Org. Chem.* **1973**, *38*, 912.
26. Tam, J. N. S.; Mojelsky, T.; Hanaya, K.; Chow, Y. L. *Tetrahedron* **1975**, *31*, 1123.
27. Jabre, I.; Saquet , M.; Thuillier, A. *J. Chem. Res. Miniprint* **1990**, *4*, 756.