Tetrahedron: Asymmetry Vol. 4, No. 4, pp. 743-756, 1993
Printed in Great Britain

0957-4166/93 $6.00+.00
Pergamon Press Ltd

Synthesis and Resolution of 1-(2-Diphenylphosphino-1-naphthyl)isoquinoline; a P-N Chelating Ligand for Asymmetric Catalysis.

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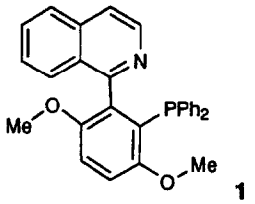
(*Received in UK* 22 *February* 1993)

Abstract. A multistep synthesis resulting in a good yield of the title compound has been developed based on the Pd-catalysed coupling of 1-chloroisoquinoline and 2-methoxy-1-naphthylboronic acid (**5**). The product is converted into the corresponding trifluoromethanesulphonate (**10**) by successive demethylation and treatment with $(CF_3CO)_2O$, followed by a further Pd-catalysed coupling with $Ph_2P(O)H$. The resulting phosphine oxide (**11**) was cleanly reduced with $HSiCl_3$. Resolution of the phosphinamine (**4**) was carried out with the Pd complex derived from (R)-(+)-dimethyl(1-(1-naphthyl)ethyl)amine and $PdCl_2$; the diastereomers were of different stabilities and solubilities and were therefore readily separated. The resolved phosphinamine, $[\alpha]_D^{22}$ ± 153 (c = 1, $CHCl_3$), was enantiomerically stable on heating to 65°C for 24h. X-ray crystal structures of the adduct (**16**) and the Pd dimer (**7**) isolated during the initial coupling reaction are presented.

In previous publications[1,2] we reported the synthesis of an atropisomerically chiral phosphinamine ligand based on biaryl linkage of isoquinoline and 2,5-dimethoxyphenyl(diphenyl)phosphine through the 1- and 6-positions respectively. The product **1** was found to racemise quite easily, with an estimated half-life of ca. 1h. at ambient temperature, and this precluded its application to asymmetric catalysis. It was shown, however, by X-ray analysis of the $PdCl_2$ complex **2**, and solution NMR studies of the two diastereomeric complexes **3**, that the phosphine and isoquinoline nitrogen were cis-chelated to palladium. The X-ray structure further revealed an interesting distortion in that the N-Pd bond in complex **2** is bent out of the plane containing the N lone-pair vector by 26°, reflecting some strain in the chelate ring. In view of the continuing success of N-P chelate catalysts derived from side-chain aminated ferrocenylphosphines initially synthesised by Hayashi and co-workers[3], and a more general current interest in chelate ligands for catalysis which do not correspond to the diphosphine model[4], we have continued this work with the object of forming an optically stable analogue of ligand **1**.



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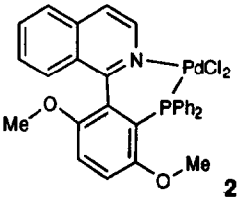

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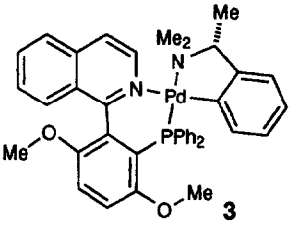

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Results and Discussion.

The method utilised[2] for the synthesis of ligand **1** was dependent on the successful preparation of an ortho-lithiated arylphosphine oxide enabled by the presence of a flanking methoxy-group[5]. When the synthesis of 1-lithio-2-diphenylphosphinylnaphthalene was attempted by proton abstraction with tert-BuLi, then conjugate addition proved to be the predominant reaction path[2]. Hence a different approach to the desired ligand **4** was required, involving the construction of the biaryl prior to the introduction of the C-P bond.

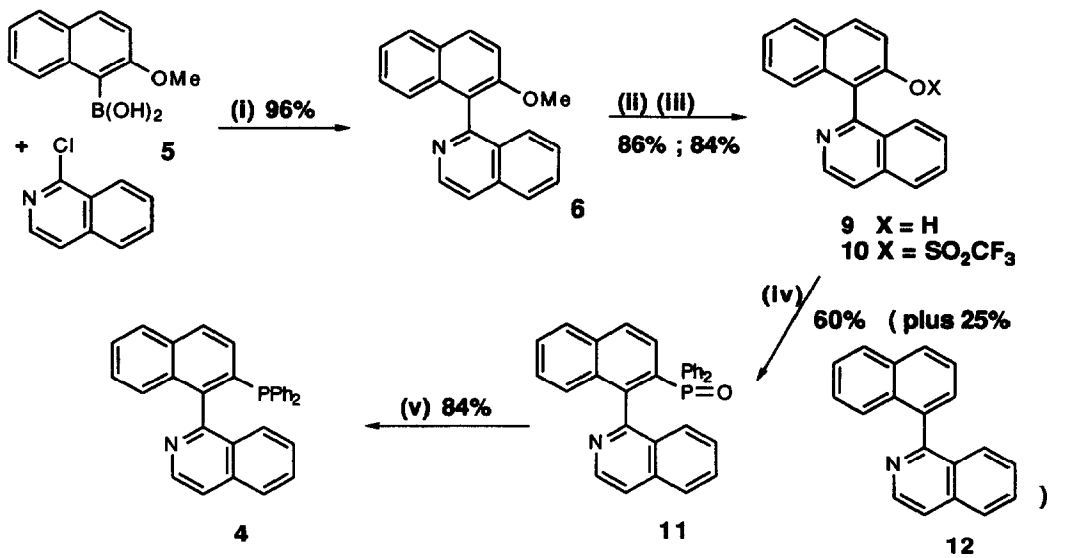
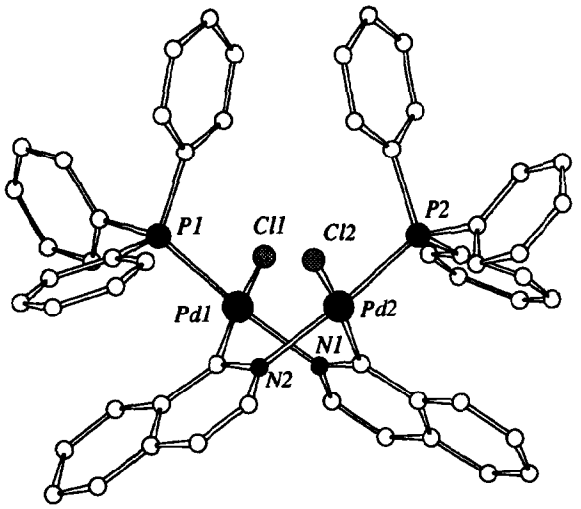


Figure 1 *(i) 3 mol% $Pd(PPh_3)_4$, 2 eq Na_2CO_3 ; DME reflux (ii) BBr_3, CH_2Cl_2 (iii) $(CF_3SO_2)O$, xs DMAP , CH_2Cl_2 (iv) 4 eq $Ph_2P(O)H$, 0.1 eq $Pd(OAc)_2$ / dppp ; 6 eq Na_2CO_3 , DMSO 85^0C, 20 h. ; (v) xs $HSiCl_3$;NEt_3.*

The palladium-catalysed condensation of arylboronic acids with aryl halides is a powerful and general method for biaryl synthesis[6]. Normally, aryl bromides or iodides are preferred because of their superior activity, but it has been noted that α-chloropyridines are sufficiently activated towards palladium-catalysed coupling reactions[7], and 1-chloroisoquinoline[8] is more readily available than the corresponding bromide or iodide. The boronic acid **5** was prepared by reacting the Grignard reagent from 1-bromo-2-methoxynaphthalene[9] with $B(OMe)_3$ in THF at -78°C, and recrystallising from CH_2Cl_2 after aqueous work-up. The cross-coupling step was achieved in high yield in the presence of 3 mol% $Pd(PPh_3)_4$, promoted by Na_2CO_3 in dimethoxyethane at reflux (Figure 1). When the reaction was carried out on a large scale, it proved convenient to separate the product **6** from the crude reaction mixture by crystallisation (diethyl ether). Under these conditions a second, Pd-containing compound was isolated and crystallised from CH_2Cl_2/Et_2O, in sufficient amount to suggest that it was the major Pd-containing species. X-ray analysis afforded the dimeric structure **7** shown in Figure 2, with C, N-bonded isoquinolines bridging the two palladium atoms, and a single PPh_3 at each metal. It is easy to see how the catalytic cycle could proceed through a monomer **8** related to

complex 7, with the aryl transferred from $ArB(OH)_2$ to displace Pd-bound Cl, followed by reductive elimination and readdition of the chloroisoquinoline moiety (Figure 3).



Selected bond lengths and angles

	Pd1	*Pd2*
P-Pd-N	170.3	171.5
C-Pd-Cl	170.1	168.2
N-Pd-C	86.0	85.8
Pd-N	2.076	2.088
Pd-P	2.282	2.280
Pd-Cl	2.383	2.391
Pd-C	1.991	1.995

Figure 2. *X-ray crystal structure of the Pd dimer 7 isolated during the cross-coupling of 1-chloroisoquinoline and 5 catalysed by* $Pd(PPh_3)_4$. $C_{54}H_{42}Cl_2N_2P_2Pd_2 ; 2CHCl_3$ *M = 1064.6 + 2* 119.4;* $P\bar{1}$; *a = 10.48 , b = 12.56, c = 21.62,* $\alpha = 81.80$, $\beta = 75.76$, $\gamma = 81.88$, *z = 4 ; R = 0.051 for 5345 unique observed* $(I/\sigma(I) \geq 2.0)$.

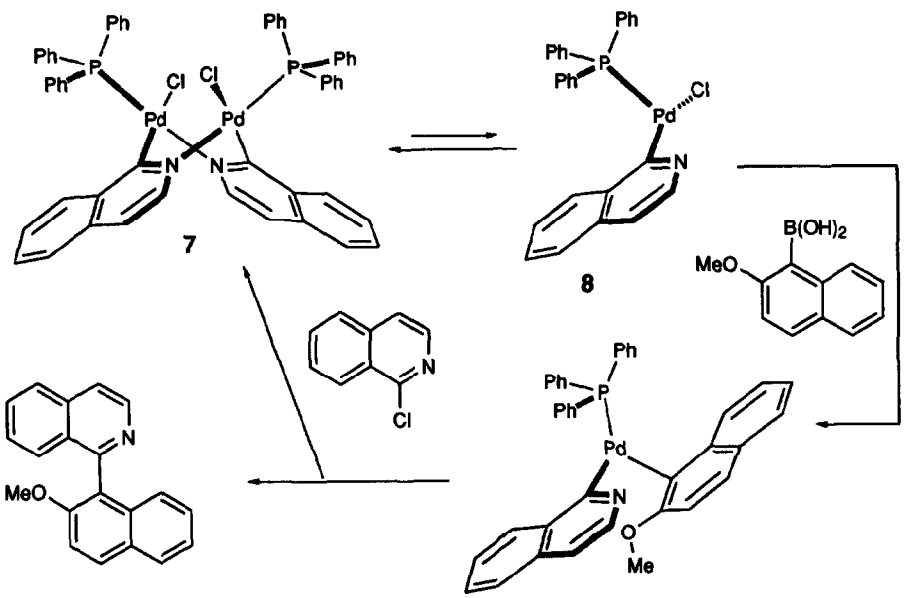
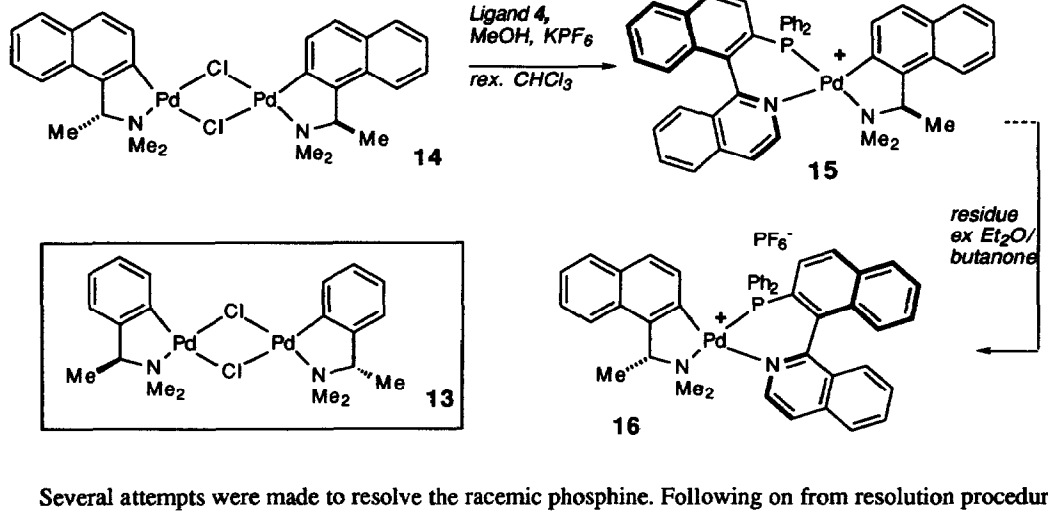


Figure 3. *Possible intermediacy of the monomer 8 in the biaryl-forming step.*

The next two stages in the synthesis were straightforward, and uneventful. Cleavage of the methyl ether with BBr_3 to give the phenol **9** occurred in high yield; a broad band in the IR spectrum (KBr) at 3440 cm^{-1} indicating intramolecular H-bonding. The phenol was converted into its trifluoromethanesulphonate with $(CF_3CO_2)_2O$ in the presence of 4-dimethylaminopyridine. Adapting the procedure of Kurz and co-workers[11], the triflate **10** was reacted with diphenylphosphine oxide catalysed by $Pd(OAc)_2$ and $Ph_2P(CH_2)_3PPh_2$ in basic aqueous DMSO, giving the desired phosphine oxide **11** in 60% yield. Under these conditions the palladium acetate is reduced to zerovalent Pd[12] and the phosphine is part-oxidised. The reaction conditions required careful optimisation, since the corresponding naphthalene **12**[13] was always formed as a by-product, assumed to be the consequence of competitive protonolysis of the Pd-C bond of the biaryl entity in a Pd-bound catalytic intermediate. It proved easy to reduce the P=O bond using the standard procedure with $HSiCl_3/NEt_3$[14] and this set of reactions permitted the overall synthesis of phosphinamine **4** on a 10 g. scale as a crystalline white solid.

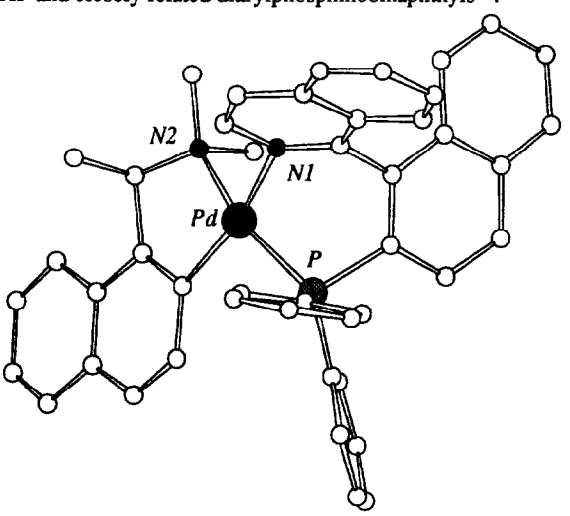


Several attempts were made to resolve the racemic phosphine. Following on from resolution procedures used[13] in the case of the parent compound **12**, a series of experiments were carried out with tartaric acid and related compounds[15], but in no case was there any evidence for the selective formation of a single diastereomeric salt. We then turned to the use of the Pd complex **13** derived from (S)-(+)-dimethyl(1-phenylethyl)amine which has been successfully utilised for phosphine and diphosphine resolutions[16]. This successfully formed a mixture of diastereomeric complexes based on interpretation of the NMR spectra, but diastereoselectivity was not apparent in their formation and attempted separation by crystallisation was unsuccessful. Quite different behaviour was observed when the corresponding complex **14** derived from (R)-(+)-dimethyl(1-(1-naphthyl)ethyl)amine was employed[17]. In this case there was a very evident differentiation between the two hands of the racemate **4**. This was manifested in different ways. For preparative purposes, it was found that mixing the ligand and dimeric complex in 2:1 molar ratio gave both the diastereomers **15** and **16**, and that their solubility properties were quite distinct. When the mixture was recrystallised from $CHCl_3$, a good recovery of a single yellow-green compound **15** , $[\alpha]_D^{21}$ = -245.3 (c = 1, acetone) was obtained. When further recrystallisation of the residue was carried out from butanone / diethyl ether the opposite diastereomer

16 $[\alpha]_D^{23}$ +227.0 (c = 1, acetone) was obtained as yellow crystals. The absolute configuration of the coordinated ligand in **16** was established by X-ray crystallography (Figure 4) to be R. As expected, the complex reveals a cis-relationship between the two nitrogen atoms. Thus the stable diastereomer has the R, S configuration and the less stable one the R, R configuration.

When the preparation of the mixed palladium complex was carried out by mixing the components **4** and **14** in a 4:1 molar ratio in MeOH, complex **15** was formed preferentially (>95:5). Furthermore, if excess racemic **4** was added to the diastereomeric mixture of **15** and **16** formed by reacting the components in 2:1 molar ratio as described above, then complex **16** disappeared so that after 2 h. at 20°C the solution was exclusively composed of **15** and excess phosphinamine. These experiments effectively demonstrate a difference in stability of the two diastereomers in solution in which **16**, the configuration defined by X-ray, is the one disfavoured.

The free ligands R-**4** $[\alpha]_D^{22}$ = 153.2 (c = 1, $CHCl_3$) and S-**4** $[\alpha]_D^{21}$ = -153.0 (c = 1, $CHCl_3$) were regenerated from the Pd complexes by treatment with 1,2-bis(diphenylphosphino)ethane in CH_2Cl_2. It is interesting to note that previous work by other authors[18] on related atropisomeric monophosphines establishes that the configuration with the same sense of binaphthyl twist as R-**4** (usually but not exclusively the R-enantiomer) invariably has a positive rotation at the Na D-line. This is also the case with the diphosphine BINAP and closely related diarylphosphinobinaphthyls[19].



Selected bond lengths and angles

P-Pd-N2	159.9
P-Pd-N1	83.4
P-Pd-C	102.3
N1-Pd-C	165.2
N1-Pd-N2	98.5
N2-Pd-C	80.9
Pd-P	2.256
Pd-N1	2.152
Pd-N2	2.166
Pd-C	2.018

Figure 4 *X-ray crystal structure (hydrogens omitted) of the yellow salt* **16** *(PF_6^- omitted), which is the less stable diastereomer involved in the resolution process, obtained from C_4H_8O / Et_2O as blocks. $C_{45}H_{38}N_2PdP_2F_6$;C_4H_8O, M = 960.2; orthorhombic, space group $P2_12_12_1$, a = 11.798 (4) b = 13.502 (5), c = 28.175 (12) Å, U = 4488 Å^3, Z = 4, R = 0.041 for 3895 unique observed reflections ($I/\sigma(I) \geq 2.0$) relections.*

The contrast in behaviour between the diastereomeric phenylethylamine salts which were inseparable and apparently of similar energy, and the 1-naphthylethylamine salts which were strikingly different from one another, needs to be explained. A hint comes from the ^1H and ^{13}C NMR spectra of the former; the benzylic C-H of one diastereomer is coupled to ^{31}P in the complex (J = 7 Hz) and the side-chain Me has a ^{13}C chemical shift of 24 ppm, whilst the other possesses no ^{31}P coupling and has a chemical shift for that carbon

of 9 ppm. Both the naphthylethylamine complexes **15** and **16** closely resemble the first of these. As delineated in Figure 5, the P-H coupling is thought to be associated with an equatorial conformation of the C-H bond, giving good overlap with the trans-N-Pd-P system. The X-ray structure of **16** clearly demonstrates this and accordingly shows that the C-methyl group is axial. An equatorial C-methyl would experience severe non-bonding interactions with the 8-position of the naphthalene. Since this makes the naphthylamine component of the complex stereochemically rigid, it heightens any differences in non-bonded interactions between the two diastereomers **15** and **16**. In contrast, the C-methyl group in the corresponding phenylethylamine complex is able to adopt either an axial or an equatorial conformation and thus alleviate any difference in strain between the diastereomeric Pd complexes.

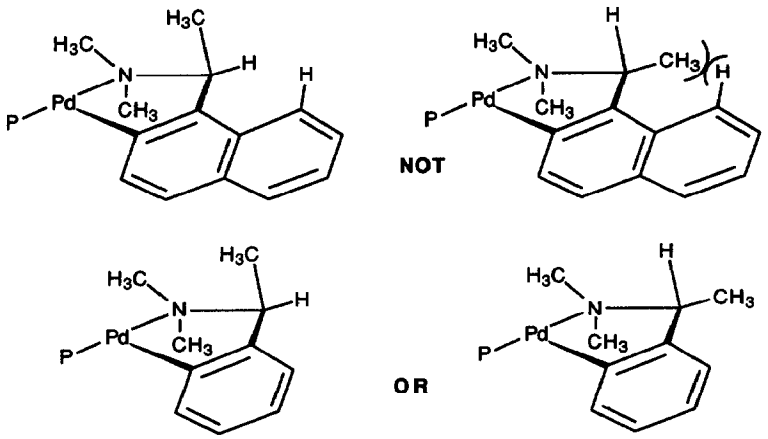


Figure 5. *Contrasting non-bonded interactions in phenyl- and 1-naphthylamine complexes*

Work in progress is directed to the catalytic behaviour of complexes of the liberated ligand **4**; the enantiomerically pure compound does not racemise appreciably on heating to 65°C for 24 h. in solution. It has already been established that a range of catalytically active chelate complexes can be formed with different metals. Some of the initial results (e.g. in the catalytic hydroboration of vinylarenes[20]) are extremely promising and will form the subject of future publications.

Acknowledgments

We thank SERC for a maintenance grant (to DIH), Dr. Simon Woodward for his early contribution, and Johnson-Matthey plc for the loan of Pd salts. Dr. Patrick J. Guiry was helpful in the obtention of high-field NMR spectra.

Experimental

General. NMR spectra were recorded on a Varian Gemini 200, Bruker AM 250, or Bruker AM 500 spectrometer. ^{1}H chemical shifts are reported in δ ppm relative to $CHCl_3$ (7.27 ppm), ^{13}C chemical shifts are reported relative to the central peak of $CDCl_3$ (77.0 ppm), and ^{31}P chemical shifts are reported relative to 85% aqueous phosphoric acid (0.0 ppm). Elemental microanalyses were carried out using a Carlo Erba 1106

elemental analyser. Mass spectra were recorded on a Trio 1, ZAB1F, or BIO-Q spectrometer. IR spectra were recorded on a Perkin Elmer 1750 FT spectrometer. Optical rotations were recorded on a Perkin Elmer 241 polarimeter. Melting points were recorded on a Reichert-Kofler block, and are uncorrected. Solvents were dried immediately before use by distillation from standard drying agents. Phosphoryl chloride, which was commercially available from BDH, was distilled under reduced pressure before use. BBr_3, 1,3-bis(diphenylphosphino)propane, 1,2-bis(diphenylphosphino)ethane, $HSiCl_3$ (Aldrich Chemical Co.), $B(OMe)_3$ (Strem Chemicals, Inc.), $(CF_3SO_2)_2O$ (Fluorochem Limited), DMAP (Janssen Chimica), and NEt_3 (Rose Chemicals Ltd.) were commercially available. $Pd(OAc)_2$ and $PdCl_2$ were obtained on loan from Johnson Matthey. $Pd(PPh_3)_4$,[21] $Ph_2P(O)H$,[22] isoquinoline N-oxide,[23] 1-bromo-2-methoxynaphthalene,[9] (+)-di-μ-chlorobis[(R)-dimethyl(1-(1-naphthyl)ethyl)aminato-C^2,N] dipalladium (II),[24] and (-)-di-μ-chlorobis[(S)-dimethyl(1-phenylethyl)aminato-C^2,N]dipalladium (II)[25] were prepared according to literature procedures.

1-Chloroisoquinoline.[8] Phosphoryl chloride (150 ml, 1.6 mol) was added slowly to a solution of isoquinoline N-oxide (82 g, 0.50 mol) in chloroform. The resulting orange solution was heated at reflux for two hours, allowed to cool to room temperature, then cautiously poured onto ice. Concentrated aqueous ammonia was added slowly until the solution was basic. The layers were separated, then the aqueous layer washed with dichloromethane (2 x 500 ml). The combined organic extracts were dried with sodium sulphate, then concentrated *in vacuo* to give a dark red oil. Kugelrohr distillation (0.4 mmHg, 130°C) gave 1-chloroisoquinoline (74 g, 80%) as a low melting white solid.

2-Methoxy-1-naphthylboronic acid, 5. Magnesium (5 g, 208 mmol) was activated by stirring overnight under argon[26]. A solution of 1-bromo-2-methoxynaphthalene[9] (30 g, 190 mmol) in THF (200ml) was added slowly *via* cannula to the magnesium in THF (50 ml), a vigorous reaction occurred giving a black suspension. The Grignard reagent was added, *via* cannula filtration, to trimethyl borate (47 ml, 570 mmol) at -78°C. THF (100 ml) was added and the mixture allowed to warm to room temperature, then stirred overnight. Water (40 ml) was added and stirred to give a clear solution with a grey precipitate. THF was removed *in vacuo* , then water (200 ml) added and the mixture extracted with dichloromethane (3 x 200 ml). The combined organic extracts were dried with magnesium sulphate then the solvent removed *in vacuo* to give a brown solid. Recrystallisation from dichloromethane gave 2-methoxy-1-naphthylboronic acid (18 g, 70%), as a white granular solid, m.p. 117-119°C. Found: C, 65.2; H, 5.26. $C_{11}H_{11}BO_3$ requires C, 65.4; H, 5.49%; ^1H NMR (250 MHz): δ ($CDCl_3$) 8.86 (d, 1H, J = 8 Hz, H_8), 7.95 (d, 1H, J = 9 Hz, H_4), 7.79 (d, 1H, J = 8 Hz, H_5), 7.52 (t, 1H, J = 8 Hz, H_7), 7.38 (t, 1H, J = 8 Hz, H_6), 7.29 (d, 1H, J = 9 Hz, H_3), 6.3 (br, s, 2H, OH), 4.04 (s, 3H, Me); ^{13}C NMR (50.3 MHz): δ (d_6-DMSO) 159.3 (C_2), 136.4 (C_9), 130.0 (CH), 129.2 (C_{10}), 128.6 (C), 128.0 (CH), 126.5 (CH), 123.7 (CH), 114.3 (C_3), 56.5 (CH_3); ν_{max} (KBr) 3306 (br, s) (O-H), 1621 (m) (Ar-H), 1590 (m) (Ar-H), 1572 (m) (Ar-H), 1509 (m) (Ar-H), 1332 (s) (B-O), 1244 (s) (C-O), 1062 (s) (C-O), and 808 (s) (Ar-H) cm^{-1}.

1-(2-Methoxy-1-naphthyl)isoquinoline, 6. 1-Chloroisoquinoline (52.9 g, 0.324 mol) was added as a solid to a solution of tetrakis(triphenylphosphine)palladium[0] (11.2 g, 9.7 mmol) in DME (600 ml), and stirred for 10 minutes under an argon atmosphere to give a yellow/green solution. 2-Methoxy-1-naphthylboronic acid (65.4 g, 0.324 mol) in the minimum amount of ethanol was added to give a yellow solution. Sodium carbonate solution (324 ml, 2 M) was added and the solution refluxed overnight (16 h). The solution was allowed to cool, and the solid filtered off. The solid was washed with dichloromethane until it

was white. The solvent was removed *in vacuo* to give a brown oil. The oil was dissolved in dichloromethane (600 ml), washed with saturated brine (2 x 300 ml), dried with sodium sulphate, and solvent removed *in vacuo* to give a brown viscous oil. Diethyl ether (500ml) was added and a white solid formed. The solid was collected by filtration, then the fitrate concentrated *in vacuo* and the process repeated. Recrystallisation from chloroform gave 1-(2-methoxy-1-naphthyl)isoquinoline (72 g, 78 %), as white needles, m.p. 130-133°C. ^{1}H NMR (500 MHz): δ ($CDCl_3$) 8.74 (d, 1H, J = 6 Hz, H_3), 8.03 (d, 1H, J = 9 Hz, $H_{4'}$), 7.93 (d, 1H, J = 8.5 Hz, H_8), 7.88 (d, 1H, J = 8.5 Hz, $H_{8'}$), 7.77 (d, 1H, J = 6 Hz, H_4), 7.68 (t, 1H, J = 7 Hz, H_7), 7.52 (d, 1H, J = 8.5 Hz, H_5), 7.45 (d, 1H, J = 9 Hz, $H_{3'}$), 7.41 (t, 1H, J = 7 Hz, H_6), 7.32 (t, 1H, J = 8 Hz, $H_{7'}$), 7.25 (t, 1H, J = 8.5 Hz, $H_{6'}$), 7.04 (d, 1H, J = 8.5 Hz, $H_{5'}$), 3.78 (s, 3H, Me); ^{13}C NMR (125.8 MHz): δ ($CDCl_3$) 157.9 (C_1), 154.6 ($C_{2'}$), 142.2 (C_3), 136.1 ($C_{9'}$), 133.6 (C_{10}), 130.3 (CH), 130.0 (CH), 128.8 (C), 128.6 (C), 127.7 (CH), 127.2 (CH), 127.0 (CH), 126.62 (CH), 126.57 (CH), 124.5 (CH), 123.5 (CH), 121.7 ($C_{1'}$), 120.0 (C_4), 113.3 ($C_{3'}$), 56.3 (CH_3); ν_{max} (KBr) 1622 (m) (Ar-H), 1594 (m) (Ar-H), 1510 (m) (Ar-H), 1264 (s) (C-O), 1250 (s) (C-O), 826 (m) (Ar-H), 812 (m) (Ar-H), and 747 (m) (Ar-H) cm^{-1}.

The residual chloroform solution was concentrated *in vacuo* to give a yellow solid. Recrystallisation (dichloromethane / diethyl ether) gave the **palladium dimer 7** as yellow needles, m.p. 272-274°C (dec.). Found: C, 60.9; H, 3.86; N, 3.3. $C_{54}H_{42}N_2P_2Pd_2Cl_2$ requires C, 60.9; H, 3.98; N, 2.7%; ^{1}H NMR (500 MHz): δ ($CDCl_3$) 8.64 (d, 2H, J = 8.7 Hz, H_8), 8.39 (dd, 2H, $J_{3,4}$ = 6.3 Hz, $J_{P,H}$ = 2.5 Hz, H_3), 7.87 (dd, 12H, $J_{o,m}$ = 7.2 Hz, $J_{P,H}$ = 11.4 Hz, *o*-H), 7.21 (t, 2H, J = 7.5 Hz, H_7), 7.20 (t, 6H, J = 7.2 Hz, *p*-H), 7.10 (t, 2H, J = 7.4 Hz, H_6), 7.09 (d, 2H, H_5), 7.07 (td, 12H, $J_{H,H}$ = 8.0 Hz, $J_{P,H}$ = 2.1 Hz, *m*-H), 6.76 (d, 2H, J = 6.3 Hz, H_4); ^{13}C NMR (62.9 MHz): δ ($CDCl_3$) 143.0 (2C, C_3), 134.8 (d, 12C, $J_{C,P}$ = 11 Hz, *o*-C), 132.7 (2C, C_{10}), 131.8 (2C, J = 4 Hz, C_9), 130.6 (d, 6C, $J_{C,P}$ = 50 Hz, *i*-C), 129.8 (6C, *p*-C), 129.6 (2C, Ar-CH), 127.8 (d, 12C, $J_{C,P}$ = 11 Hz, *m*-C), 126.4 (2C, Ar-CH), 125.9 (2C, Ar-CH), 116.8 (2C, C_4); ^{31}P NMR (101.3 MHz): δ ($CDCl_3$) 27.16; ν_{max} (KBr) 3051 (w) (Ar-H), 1615 (w) (Ar-H), 1588 (w) (Ar-H), 1539 (m) (Ar-H),1482 (m) (Ar-H), 1435 (s) (P-Ph), 1297 (m), 1097 (m), 810 (m) (Ar-H), 748 (s) (Ar-H), and 695 (s) (Ar-H) cm^{-1}; m/z (FAB+) 1064 (0.1%, M^+), 1026 (2, M-Cl), 768 (13, M-PPh_3-Cl), 736 (15, M-PPh_3-2Cl), 600 (21, M-PPh_3-2Cl-C_9H_6N), 130 (100, C_9H_8N).

When the experiment was carried out on a 1g. scale with 1.5 eq. of 2-methoxy-1-naphthylboronic acid, and product isolated by flash chromatography, a 96% yield was obtained.

1-(2-Hydroxy-1-naphthyl)isoquinoline, 9. Boron tribromide[10] (45 ml, 0.48 mol) was placed in a pressure equalising dropping funnel under argon and added, dropwise with stirring, to a solution of 1-(2-methoxy-1-naphthyl)isoquinoline (68.4 g, 0.24 mol) in dry dichloromethane (1 l). The yellow solution heated up and turned black. The solution was allowed to cool overnight, then water (500 ml) was added cautiously, white fumes were evolved and a yellow precipitate formed. The mixture was stirred for 15 minutes, then the solid was collected by filtration. The aqueous layer was neutralised with sodium hydroxide solution, then extracted with dichloromethane. Aqueous hydrochloric acid (10%) was stirred with the dichloromethane extracts, and more yellow precipitate formed which was collected by filtration. The yellow solid was stirred with dichloromethane (500 ml) and sodium carbonate solution (200 ml, 2 M) to give a pale pink solution. The organic phase was separated, and the aqueous phase washed with more dichloromethane (200 ml). The combined organic extracts were concentrated to 200 ml, and a solid precipitated. This was filtered and washed with dichloromethane to give 1-(2-hydroxy-1-naphthyl)isoquinoline (56 g, 86%), as a white solid, m.p. 244-245°C. Found: C, 84.4; H, 4.65; N, 5.1. $C_{19}H_{13}NO$ requires C, 84.1; H, 4.83; N, 5.2%; ^{1}H NMR (500 MHz):

δ ($CDCl_3$) 8.65 (d, 1H, J = 5.7 Hz, H_3), 7.94 (d, 1H, J = 8.3 Hz, H_8), 7.85 (d, 1H, J = 8.1 Hz, $H_{8'}$), 7.84 (d, 1H, J = 8.9 Hz, $H_{4'}$), 7.78 (d, 1H, J = 5.7 Hz, H_4), 7.72 (t, 1H, J = 7.6 Hz, H_7), 7.61 (d, 1H, J = 8.5 Hz, H_5), 7.41 (t, 1H, J = 7.6 Hz, H_6), 7.33 (t, 1H, J = 7.6 Hz, $H_{7'}$), 7.28 (d, 1H, J = 8.9 Hz, $H_{3'}$), 7.23 (t, 1H, J = 7.6 Hz, $H_{6'}$), 7.13 (d, 1H, J = 8.5 Hz, $H_{5'}$); ^{13}C NMR (62.9 MHz): δ ($CDCl_3$) 157.8 (C_1), 152.9 ($C_{2'}$), 141.7 (C_3), 136.8 ($C_{9'}$), 133.6 (C_{10}), 130.7 (CH), 130.6 (CH), 128.6 (C_9), 128.0 (CH), 127.9 (CH), 127.5 (CH), 126.9 (CH), 126.5 (CH), 124.6 (CH), 123.1 (CH), 120.8 (C_4), 118.7 ($C_{3'}$), 117.9 ($C_{1'}$); ν_{max} (KBr) 3437 (br, s) (O-H), 1623 (m) (Ar-H), 1587 (m) (Ar-H), 1558 (m) (Ar-H), 1513 (m) (Ar-H), 1017 (br, vs), 818 (m) (Ar-H), and 750 (m) (Ar-H) cm^{-1}; m/z (CI) 272 (100%, $M+H^+$).

1-(2-Trifluoromethanesulphonyloxy-1-naphthyl)isoquinoline, 10. Trifluoromethanesulphonic anhydride (60 g, 211 mmol) was placed in a pressure equalising dropping funnel under argon and added, dropwise with stirring, to a solution of 1-(2-hydroxy-1-naphthyl)isoquinoline (52 g, 192 mmol) and 4-dimethylaminopyridine (71 g, 576 mmol) in dry dichloromethane (1 l). The resulting brown solution was left overnight, then washed with 1M hydrochloric acid (3 x 1 l), water (2 x 1 l), and saturated brine (1 l). The solution was dried with magnesium sulphate, then the solvent removed *in vacuo* to give 1-(2-trifluoromethanesulphonyloxy-1-naphthyl)isoquinoline (64.6 g, 84%), as a white solid, m.p. 98-100°C. Found: C, 59.7; H, 2.87; N, 3.6. $C_{20}H_{12}NO_3SF_3$ requires C, 59.6; H, 3.00; N, 3.5 %; ^1H NMR (500 MHz): δ ($CDCl_3$) 8.79 (d, 1H, J = 5.7 Hz, H_3), 8.11 (d, 1H, J = 9.1 Hz, $H_{4'}$), 8.00 (d, 1H, J = 8.3 Hz, H_8), 7.97 (d, 1H, J = 8.3 Hz, $H_{8'}$), 7.85 (d, 1H, J = 5.7 Hz, H_4), 7.72 (ddd, 1H, J = 2.1, 6.0, 8.2 Hz, H_7), 7.62 (d, 1H, J = 9.1 Hz, $H_{3'}$), 7.57 (t, 1H, J = 7.6 Hz, $H_{7'}$), 7.49-7.43 (m, 2H, H_5 + H_6), 7.40 (t, 1H, J = 7.7 Hz, $H_{6'}$), 7.29 (d, 1H, J = 8.5 Hz, $H_{5'}$); ^{13}C NMR (62.9 MHz): δ ($CDCl_3$) 154.1 (C_1), 145.1 ($C_{2'}$), 142.7 (C_3), 136.4 ($C_{9'}$), 133.3 (C_{10}), 132.6 ($C_{10'}$), 131.3 (CH), 130.6 (CH), 129.5 ($C_{1'}$), 128.6 (C_9), 128.3 (CH), 127.9 (CH), 127.8 (CH), 127.2 (CH), 127.2 (CH), 126.8 (CH), 126.6 (CH), 121.3 ($C_{3'}$), 119.5 (C_4); ν_{max} (KBr) 3060 (w) (Ar-H), 1621 (m) (Ar-H), 1584 (m) (Ar-H), 1558 (m) (Ar-H), 1511 (w) (Ar-H), 1424 (s) (-SO_3-), 1212 (s) (-SO_3-), 1145 (s) (C-O), 830 (s) (Ar-H), 810 (s) (Ar-H), and 750 (s) (Ar-H) cm^{-1}; m/z (CI) 404 (100%, $M+H^+$), 270 (50, M-Tf), 254 (15, M-OTf).

1-(2-Diphenylphosphinyl-1-naphthyl)isoquinoline, 11.[27] Dry dimethylsulphoxide (1 l) was placed in a 2-litre 3-necked flask, equipped with an overhead stirrer, and argon bubbled through for 20 minutes. 1-(2-Trifluoromethanesulphonyloxy-1-naphthyl)isoquinoline (64.6 g, 124 mmol), diphenylphosphine oxide (100.2 g, 496 mmol), 1,3-bis(diphenylphosphino)propane (5.11 g, 12.4 mmol), palladium acetate (2.78 g, 12.4 mmol), and sodium hydrogencarbonate (62.5 g, 744 mmol) were added as solids against an argon counterflow. The mixture was heated at 85°C, with stirring, for 20 hours. The dark red solution was allowed to cool to room temperature then added to dichloromethane (2.5 l), washed with water (2 x 2.5 l), saturated sodium carbonate solution (2.5 l), water (2 x 2.5 l), and saturated brine (2.5 l). The solution was dried with magnesium sulphate then the solvent removed *in vacuo* to give a dark red viscous oil. Toluene (250 ml) was added and an off-white solid precipitated which was collected by filtration. The filtrate was concentrated *in vacuo* and the process repeated several times. The combined solids were recrystallised from toluene to give 1-(2-diphenylphosphinyl-1-naphthyl)isoquinoline (34 g, 60%), as a white powder, m.p. 215-218°C. Found: C, 81.6; H, 5.05; N, 2.9. $C_{31}H_{22}NOP$ requires C, 81.7; H, 4.87; N, 3.1%; ^1H NMR (500 MHz): δ ($CDCl_3$) 8.38 (d, 1H, J = 5.7 Hz, H_3), 8.14 (dd, 1H, $J_{P,H}$ = 10.9 Hz, $J_{3',4'}$ = 8.7 Hz, $H_{3'}$), 8.09 (dd, 1H, $J_{3',4'}$ = 8.7 Hz, $J_{P,H}$ = 2.2 Hz, $H_{4'}$), 7.95 (d, 1H, J = 8.2 Hz, $H_{8'}$), 7.86 (dd, 2H, $J_{P,H}$ = 12.1 Hz, $J_{o,m}$ = 9.0 Hz, *o*-H[A]), 7.64 (d, 1H, J = 8.3 Hz, H_8), 7.54 (t, 1H, J = 8.2 Hz, $H_{7'}$), 7.52 (td, 1H, J = 8.3, 1.4 Hz, H_7), 7.48 (td, 1H, $J_{m,p}$ = 7.6 Hz,

$J_{P,H}$ = 1.5 Hz, *p*-H[A]), 7.44 (d, 1H, J = 5.7 Hz, H_4), 7.41 (td, 2H, $J_{H,H}$ = 7.8 Hz, $J_{P,H}$ = 2.9 Hz, *m*-H[A]), 7.25 (t, 1H, J = 7.7 Hz, $H_{6'}$), 7.24 (t, 1H, J = 8.1 Hz, H_6), 7.20 (d, 1H, J = 7.8 Hz, H_5), 7.10 (dd, 2H, $J_{o,m}$ = 8.3 Hz, $J_{P,H}$ = 12.4 Hz, *o*-H[B]), 6.98 (td, 1H, $J_{m,p}$ = 7.5 Hz, $J_{P,H}$ = 1.4 Hz, *p*-H[B]), 6.88 (d, 1H, J = 8.6 Hz, $H_{5'}$), 6.83 (td, 2H, $J_{H,H}$ = 7.7 Hz, $J_{P,H}$ = 3.1 Hz, *m*-H[B]); ^{13}C NMR (50.3 MHz): δ ($CDCl_3$) 158.6 (d, $J_{P,C}$ = 4 Hz, C_1), 141.8 (C_3), 136-126 (Ar-C), 121.3 (C_4); ^{31}P NMR (101.3 MHz): δ ($CDCl_3$) 30.6; ν_{max} (KBr) 1619 (w) (Ar-H), 1584 (w) (Ar-H), 1557 (w) (Ar-H), 1437 (w) (PPh), 1199 (s) (P=O), 754 (m) (Ar-H), and 702 (m) (Ar-H) cm^{-1}; m/z (DCI) 456 (100%, M+H$^+$), 378 (8, M-Ph), 254 (9, M-P(O)Ph_2), 203 (33, Ph_2P(OH)H).

(R,S)-1-(2-Diphenylphosphino-1-naphthyl)isoquinoline, (R,S)-4. 1-(2-Diphenylphosphinyl-1-naphthyl)isoquinoline (12 g, 26.4 mmol) was placed in a 2-litre 2-necked flask under argon, then toluene (1 l) added and stirred to give a white suspension. Trichlorosilane (20 ml, 200 mmol) then triethylamine (35 ml, 250 mmol) were added, and white fumes were evolved. The solution was refluxed for 2 hours, then cooled to 0°C and 2N sodium hydroxide solution (1 l) added cautiously with vigorous stirring. The layers were separated and the aqueous layer extracted with dichloromethane (1 l). The combined organic extracts were dried with magnesium sulphate, then the solvent removed *in vacuo* to give a pale orange solid. Recrystallisation from dichloromethane gave 1-(2-diphenylphosphino-1-naphthyl)isoquinoline (9.7 g, 84%), as a white solid, m.p. 217-219°C. Found: C, 84.9; H, 5.02; N, 3.0. $C_{31}H_{22}NP$ requires C, 84.7; H, 5.05; N, 3.2%; ^{1}H NMR (500 MHz): δ (C_6D_6) 8.58 (d, 1H, J = 5.7 Hz, H_3), 7.61 (d, 1H, J = 8.5 Hz, $H_{4'}$), 7.58 (d, 1H, J = 8.5 Hz, $H_{8'}$), 7.56 (dd, 1H, $J_{3',4'}$ = 8.5 Hz, $J_{P,H}$ = 2.9 Hz, $H_{3'}$), 7.44 (d, 1H, J = 8.3 Hz, H_8), 7.38 (t, 2H, J = 7.5 Hz, *m*-Ph), 7.35 (d, 1H, H_5), 7.30 (m, 2H, m'-Ph), 7.28 (d, 1H, $H_{5'}$), 7.26 (d, 1H, J = 5.7 Hz, H_4), 7.16 (t, 1H, $H_{7'}$), 7.15 (t, 1H, H_7), 7.05-6.98 (m, 6H, *o*+*p*-Ph), 6.95 (t, 1H, $J_{6',5'}$ = 8.5 Hz, $J_{6',7'}$ = 6.8 Hz, $H_{6'}$), 6.86 (t, 1H, $J_{6,5}$ = 8.5 Hz, $J_{6,7}$ = 6.8 Hz, H_6); ^{13}C NMR (62.9 MHz): δ ($CDCl_3$) 160.5 (d, $J_{P,C}$ = 8 Hz, C_1), 144.4 (d, $J_{P,C}$ = 33 Hz, $C_{2'}$), 142.3 (C_3), 137.4 (m, *i* + *i'*), 135.9 ($C_{10'}$), 134.9 (d, $J_{P,C}$ = 13 Hz, $C_{1'}$), 133.7 (d, $J_{P,C}$ = 20 Hz, *o*-C), 133.6 (C_{10}), 133.2 (d, $J_{P,C}$ = 19 Hz, *o'*-C + $C_{3'}$), 132.7 (d, $J_{P,C}$ = 7 Hz, $C_{9'}$), 131-126 (Ar-C), 120.3 (C_4); ^{31}P NMR (101.3 MHz): δ ($CDCl_3$) -13.1; ν_{max} (KBr) 3052 (w) (Ar-H), 1619 (m) (Ar-H), 1583 (m) (Ar-H), 1556 (m) (Ar-H), 1433 (m) (P-Ph), 745 (s) (Ar-H), and 696 (s) (Ar-H) cm^{-1}; m/z (FAB+) 440 (100%, M+H$^+$), 362 (82, M-Ph), 285 (12, M-2Ph), 254 (16, M-PPh_2).

Resolution of (R,S)-4: Formation of diastereomers (R,S)-15 and (R,R)-16. (+)-Di-μ-chlorobis[(R)-dimethyl(1-(1-naphthyl)ethyl)aminato-C^2,N]dipalladium (II) (160 mg, 0.235 mmol) and 1-(2-diphenylphosphino-1-naphthyl)isoquinoline (210 mg, 0.478 mmol) were placed in a Schlenk tube under argon. Degassed methanol (25 ml) was added *via* syringe and stirred until the solids had dissolved to give a pale yellow/green solution. Potassium hexafluorophosphate (85 mg, 0.462 mmol) in water (20 ml) was added *via* syringe with vigorous stirring, and a very pale green solid precipitated. The solid was collected by filtration, and washed with ether to give a 1:1 mixture of (R,R)- and (R,S)-cis-[dimethyl(1-(1-naphthyl)ethyl)aminato-C^2,N]-[1-(2-diphenylphosphino-1-naphthyl)isoquinoline]palladium (II) hexafluoro phosphate as a very pale green solid (389 mg, 92%).

(-)-cis-[(R)-Dimethyl(1-(1-naphthyl)ethyl)aminato-C^2,N]-[(S)-1-(2-diphenylphosphino-1-naphthyl)isoquinoline]palladium (II) hexafluorophosphate, (R,S)-15. Crystallisation of the racemic mixture from chloroform gave (-)-cis-[(R)-dimethyl(1-(1-naphthyl)ethyl)aminato-C^2,N]-[(S)-1-(2-diphenylphosphino-1-naphthyl)isoquinoline]palladium (II) hexafluorophosphate as very pale green hexagonal prisms, m.p. 228-230°C. ^{1}H NMR (500 MHz): δ (d_6-acetone) 9.01 (d, 1H, J = 6.2 Hz, H_3), 8.32 (dd, 1H, $J_{3',4'}$ = 8.5 Hz, $J_{P,H}$ = 1.8 Hz, $H_{4'}$), 8.20 (d, 1H, J = 8.3 Hz, $H_{8'}$), 8.13 (d, 1H, J = 6.2 Hz, H_4), 7.97 (d, 1H, J = 8.2

Hz, H_8), 7.79 (d, 1H, J = 8.3 Hz, H_c), 7.79 (t, 1H, J = 7.6 Hz, H_7), 7.72 (t, 1H, J = 7.5 Hz, $H_{7'}$), 7.71 (d, 1H, J = 8.0 Hz, H_f), 7.61 (t, 2H, J = 7.6 Hz, *m*-Ph), 7.47-7.39 (m, 4H, $H_{6'}$ + H_6 + Ph-H), 7.39-7.33 (m, 4H, $H_{3'}$ + H_d + H_e + Ph-H), 7.26 (d, 1H, J = 8.5, $H_{5'}$), 7.15 (dd, 2H, J = 8.2, 9.1 Hz, *o*-H), 7.09 (t, 2H, *m*-H), 7.06 (d, 1H, J = 8.5 Hz, H_b), 7.00 (d, 1H, J = 8.5, H_5), 6.99 (br, 1H, *p*-Ph), 6.61 (dd, 1H, $J_{a,b}$ = 8.5 Hz, $J_{P,H}$ = 5.8 Hz, H_a), 4.61 (quin, 1H, J = 6 Hz, C<u>H</u>Me), 2.95 (d, 3H, $J_{P,H}$ = 2.2 Hz, NMe), 2.81 (d, 3H, $J_{P,H}$ = 3.5 Hz, NMe), 1.75 (d, 3H, J = 6.3 Hz, CH<u>Me</u>); ^{13}C NMR (62.9 MHz): δ (d_6-acetone) 150.6 (d, $J_{P,C}$ = 16 Hz, C_1), 141.9 (C_3), 137.7 (d, $J_{P,C}$ = 11 Hz, $C_{3'}$), 136.2 (d, $J_{P,C}$ = 11 Hz, *o*-C), 136-123 (Ar-C), 74.0 (d, $J_{P,C}$ = 3 Hz, <u>C</u>HMe), 51.9 (NMe), 48.1 (NMe), 24.2 (CH<u>Me</u>); ^{31}P NMR (101.3 MHz): δ (d_6-acetone) 40.5 (s, -PPh_2), -50.7 (heptet, $J_{P,F}$ = 713 Hz, PF_6); ν_{max} (KBr) 1619 (w) (Ar-H), 1592 (w) (Ar-H), 1573 (w) (Ar-H), 1503 (w) (Ar-H), 1435 (m) (P-Ph), 844 (vs) (P-F), 745 (m) (Ar-H), 703 (w) (Ar-H), and 694 (w) (Ar-H) cm^{-1}; m/z (FAB+) 743 (100%, M^+), 546 (30, M-NpCHMeNMe_2), 362 (93, M-NpCHMeNMe_2Pd), 254 (32, M-NpCHMeNMe_2PdPPh_2); $[\alpha]_D^{21}$ = -245.3 (c = 1, acetone).

(+)-cis-[(R)-Dimethyl(1-(1-naphthyl)ethyl)aminato-C^2,N]-[(R)-1-(2-diphenylphosphino-1-naphthyl)isoquinoline]palladium (II) hexafluorophosphate, (R,R)-16. After crystallisation of the (R,S)-diastereomer the residual solution was reduced *in vacuo* to a solid. Crystallisation from butanone / diethyl ether gave (+)-cis-[(R)-dimethyl(1-(1-naphthyl)ethyl)aminato-C^2,N]-[(R)-1-(2-diphenylphosphino-1-naphthyl)isoquinoline]palladium (II) hexafluorophosphate butanone solvate as yellow cubes, m.p. 216-219°C. Found: C, 61.4; H, 4.89; N, 2.8. $C_{49}H_{46}N_2OP_2PdF_6$ requires C, 61.2; H, 4.82; N, 2.9%; ^{1}H NMR (500 MHz): δ (d_6-acetone) 9.18 (d, 1H, J = 6.2 Hz, H_3), 8.36 (d, 1H, J = 8.6 Hz, $H_{4'}$), 8.21 (d, 1H, J = 8.3 Hz, $H_{8'}$), 8.12 (d, 1H, J = 6.2 Hz, H_4), 7.94 (d, 1H, J = 8.2 Hz, H_8), 7.84 (d, 1H, J = 8.4 Hz, H_c), 7.80 (t, 1H, *p*-H), 7.78 (t, 1H, J = 7.5 Hz, H_7), 7.74 (t, 1H, J = 7.6 Hz, $H_{7'}$), 7.70 (d, 1H, J = 8.0 Hz, H_f), 7.64 (t, 2H, J = 7.5 Hz, *m*-Ph), 7.57 (dd, 2H, *o*-Ph), 7.53 (t, 1H, J = 7.7 Hz, $H_{6'}$), 7.47 (t, 1H, J = 7.7 Hz, H_6), 7.44-7.34 (m, 6H, Ar-H), 7.07-6.95 (m, 5H, Ar-H), 6.48 (dd, 1H, $J_{a,b}$ = 8.5 Hz, $J_{P,H}$ = 6.7 Hz, H_a), 4.82 (quin, 1H, J = 6.3 Hz, C<u>H</u>Me), 2.99 (m, 6H, NMe_2), 1.89 (d, 3H, J = 6.3 Hz, CH<u>Me</u>); ^{13}C NMR (62.9 MHz): δ ($CDCl_3$) 156.8 (d, $J_{P,C}$ = 8 Hz, C_1), 150.7, 143.5, 141.2 (C_3), 140.1 (d, $J_{P,C}$ = 11 Hz), 137-122 (Ar-C), 71.5 (d, $J_{P,C}$ = 4 Hz, <u>C</u>HMe), 54.1 (d, $J_{P,C}$ = 3 Hz, NMe), 47.5 (NMe), 24.2 (CH<u>Me</u>); ^{31}P NMR (101.3 MHz): δ (d_6-acetone) 42.2 (s, -PPh_2), -50.7 (heptet, $J_{P,F}$ = 713 Hz, PF_6); ν_{max} (KBr) 1620 (w) (Ar-H), 1574 (w) (Ar-H), 1503 (w) (Ar-H), 1438 (m) (P-Ph), 842 (vs) (P-F), 747 (m) (Ar-H), and 702 (w) (Ar-H) cm^{-1}; m/z (ES+) 743 (100%, M^+); $[\alpha]_D^{23}$ = +227.0 (c = 1, acetone); +247.0 (c = 1, $CHCl_3$).

(-)-(S)-1-(2-Diphenylphosphino-1-naphthyl)isoquinoline, (S)-4. 1,2-Bis(diphenylphosphino)ethane (201 mg, 0.51 mmol) was added to a solution of (-)-cis-[(R)-dimethyl(1-(1-naphthyl)ethyl)aminato-C^2,N]-[(S)-1-(2-diphenylphosphino-1-naphthyl)isoquinoline]palladium (II) hexafluorophosphate (450 mg, 0.51 mmol) in dichloromethane (50 ml). The solution was stirred for ten minutes then the volume reduced *in vacuo* to ~10 ml. Toluene (20 ml) was added then the solvent removed *in vacuo* to leave a white solid. Toluene (20 ml) was added and the suspension stirred for five mins. The solid was removed by filtration then the solvent removed *in vacuo* to leave a white solid. Methanol (10 ml) was added and the suspension stirred for five minutes. The solid was collected by filtration to give (-)-(S)-1-(2-diphenylphosphino-1-naphthyl)isoquinoline (195 mg, 88%) as a white powder, m.p. 226-231°C. $[\alpha]_D^{21}$ = -153.0 (c = 1, $CHCl_3$).

(+)-(R)-1-(2-Diphenylphosphino-1-naphthyl)isoquinoline, (R)-4. The same procedure as for (S)-4 was followed to give (+)-(R)-1-(2-diphenylphosphino-1-naphthyl)isoquinoline. $[\alpha]_D^{22}$ = +153.2 (c = 1, $CHCl_3$).

Formation of (S,S)- and (S,R)-cis-[dimethyl(1-phenylethyl)aminato-C^2,N]-[1-(2-diphenyl phosphino-1-naphthyl)isoquinoline]palladium (II) hexafluorophosphate. (+)-Di-μ-chlorobis[(S)-dimethyl (1-phenylethyl)aminato-C^2,N)]dipalladium (II) (66 mg, 0.114 mmol) and 1-(2-diphenylphosphino-1-naphthyl) isoquinoline (100 mg, 0.227 mmol) were placed in a Schlenk tube under argon. Degassed MeOH (10 ml) was added *via* syringe and stirred until the solids had dissolved. KPF_6 (42 mg, 0.227 mmol) in water (20 ml) was added *via* syringe with vigorous stirring, and a white solid precipitated. The solid was collected by filtration, and washed with ether to give a 1:1 mixture of (S,S)- and (S,R)-cis-[dimethyl(1-phenylethyl)aminato-C^2,N]-[1-(2-diphenylphosphino-1-naphthyl)isoquinoline]palladium (II) hexafluorophosphate (141 mg, 74%) as a white solid, m.p. 270-275°C (dec.). Found: C, 58.6; H, 4.13; N, 3.1. $C_{41}H_{36}N_2P_2PdF_6$ requires C, 58.7; H, 4.33; N, 3.3%; ^{1}H NMR (500 MHz): δ ($CDCl_3$) 8.79 (d, 1H, J = 6.2 Hz, H_3), 8.77 (d, 1H, J = 6.2 Hz, H_3), 8.11-8.04 (m, 6H, Ar-H), 7.81 (d, 2H, J = 8.3, Ar-H), 7.7-6.8 (m, 38H, Ar-H), 6.54-6.48 (m, 2H, Ph-H), 6.31-6.26 (m, 2H, Ph-H), 4.73 (q, 1H, J = 6.7 Hz, C<u>H</u>Me), 3.53 (quin, 1H, J = 6.3 Hz, C<u>H</u>Me), 2.95 (d, 3H, $J_{P,H}$ = 2.0 Hz, NMe), 2.86 (d, 3H, $J_{P,H}$ = 3.1 Hz, NMe), 2.66 (d, 3H, $J_{P,H}$ = 2.4 Hz, NMe), 2.62 (d, 3H, $J_{P,H}$ = 3.3 Hz, NMe), 1.60 (d, 3H, J = 6.4 Hz, CH<u>Me</u>), 1.37 (d, 3H, J = 6.7 Hz, CH<u>Me</u>); ^{13}C NMR (62.9 MHz): δ ($CDCl_3$) 156.8 (d, $J_{P,C}$ = 7 Hz, C_1), 154.9, 152.8, 151.1, 149.5, 141-122 (Ar-C), 76.4 (<u>C</u>HMe), 72.2 (<u>C</u>HMe), 51.6 (NMe), 48.2 (NMe), 47.5 (NMe), 42.0 (NMe), 25.2 (CH<u>Me</u>), 9.2 (CH<u>Me</u>); ^{31}P NMR (101.3 MHz): δ ($CDCl_3$) 40.5 (s, -PPh_2), 40.2 (s, -PPh_2), -41.3 (heptet, $J_{P,F}$ = 713 Hz, PF_6); ν_{max} (KBr) 1439 (m) (P-Ph), 843 (vs) (P-F), 753 (m) (Ar-H), 703 (m) (Ar-H), and 694 (m) cm^{-1}; m/z (FAB+) 693 (31%, M^+), 546 (18, M-$PhCHMeNMe_2$), 362 (47, M-$PhCHMeNMe_2Pd$), 254 (17, M-$PhCHMeNMe_2PdPPh_2$), 148 (100, $PhCHMeNMe_2$).

X-ray crystal structure of palladium dimer 7: Crystals were obtained from $CHCl_3/Et_2O$. Character: bright yellow plates. Data were collected with a Siemens R3m four circle diffractometer in ω-2θ mode. The crystal was held at 220 K with an Oxford Cryosystems Cryostream Cooler. Maximum 2θ was 47° with scan range ± 0.75°(ω) around the $K_{\alpha 1}$-$K_{\alpha 2}$ angles, scan speed 2.4-15°(ω) min^{-1}, depending on the intensity of a 2s pre-scan; backgrounds were measured at each end of the scan for 0.25 of the scan time; hkl rangeswere: 0/11; -14/14; -24/24. Three standard reflections were monitored every 200 reflections, and showed a slight decrease (4%) during data collection. The data were rescaled to correct for this. Unit cell dimensions and standard deviations were obtained by least-squares fit to 15 reflections ($16<2\theta<18°$); although originally a reduced triclinic cell was chosen, the small changes in the refined cell constants has led to the true reduced cell differing from that used for data collection and refinement. The 8181 reflections collected (all unique) were processed using profile analysis; 5345 were considered observed ($I/\sigma(I) >= 2.0$). These were corrected for Lorentz, polarization and absorption effects (by the Gaussian method); minimum and maximum transmission factors were 0.87 and 0.92. Crystal dimensions were 0.087 x 0.16 x 0.27 mm. No systematic reflection conditions; space group $P\bar{1}$ was initially selected and shown to be correct by successful refinement. Heavy atoms were located by the Patterson interpretation section of SHELXTL and the light atoms then found by E-map expansion and successive Fourier syntheses; the asymmetric unit contains two solvent chloroform molecules. Anisotropic temperature factors were used for all non-H atoms. Hydrogen atoms were given fixed isotropic temperature factors, U = 0.08 $Å^2$, were inserted at calculated positions and not refined. Final refinement was on F by least squares methods refining 631 parameters. Largest positive and negative peaks on a final difference Fourier synthesis were of height + 0.9 el. $Å^{-3}$. A weighting scheme of the form $W = 1/(\sigma^2(F) + gF^2)$ with g = 0.00036 was used and shown to be satisfactory by a weight analysis. Final R = 0.051, R_w =

0.050, S = 1.29; R(all reflections) = 0.091. Maximum shift/error in final cycle 0.06. Computing with SHELXTL PLUS (Sheldrick, 1986) on a DEC Microvax-II. Scattering factors in the analytical form and anomalous dispersion factors taken from International Tables (1974). Final atomic co-ordinates and selected bond lengths and angles are appended along with the observed and calculated structure factors[28].
Full structural details have been deposited with the Cambridge Crystallographic Centre.

X-ray Crystal Structure of (+)-cis-[(R)-Dimethyl(1-(1-naphthyl)ethyl)aminato-C^2,N]-[(R)-1-(2-diphenylphosphino-1-naphthyl)isoquinoline]palladium (II) hexafluorophosphate, (R,R)-16:
Crystals were obtained from 2-butanone/Et_2O as green-yellow blocks, suffering slow solvent loss. Data were collected with a Siemens R3m four circle diffractometer in ω-2θ mode. The crystal was held at 200 K with an Oxford Cryosystems Cryostream Cooler. Maximum 2θ was 50° with scan range $\pm$ 0.7°(ω) around the $K_{\alpha 1}$-$K_{\alpha 2}$ angles, scan speed 2.5-15°(ω) min^{-1}, depending on the intensity of a 2s pre-scan; backgrounds were measured at each end of the scan for 0.25 of the scan time; hkl ranges were: 0/14; 0/16; 0/33. Three standard reflections were monitored every 200 reflections, and showed a slow decrease during data collection (8%). The data were rescaled to correct for this. Unit cell dimensions and standard deviations were obtained by least-squares fit to 15 reflections (26<2θ<30°). Reflections were processed using profile analysis to give 4405 unique reflections, of which 3895 were considered observed ($I/\sigma(I) \geq 2.0$). These were corrected for Lorentz, polarization and absorption effects (by the Gaussian method); minimum and maximum transmission factors were 0.80 and 0.92. Crystal dimensions were 0.87 x 0.53 x 0.23 mm. Systematic reflection conditions h00, h = 2n; 0k0, k = 2n; 0 0 1, l = 2n: indicate spacegroup $P2_12_12_1$. Heavy atoms were located by the Patterson interpretation section of SHELXTL and the light atoms then found by E-map expansion and successive Fourier syntheses, including a molecule of solvent. Anisotropic temperature factors were used for all non-H atoms. Hydrogen atoms were given fixed isotropic temperature factors, U = 0.08 $Å^2$. Those defined by the molecular geometry were inserted at calculated positions and not refined; methyl groups were treated as rigid CH_3 units, with their initial orientation with their initial orientation based on a staggered configuration. The absolute structure was checked by refinement of a $\delta f''$ multiplier, which confirmed the chirality assigned on the basis of the known conformation at Cl. Final refinement was on F by least squares methods refining 560 parameters, including an extinction parameter (final value 0.00043(5)). Largest positive and negative peaks on a final difference Fourier synthesis were of height $\pm$ 0.9 el. $Å^{-3}$. A weighting scheme of the form $W = 1/(\sigma^2(F) + gF^2)$ with g = 0.00033 was used and shown to be satisfactory by a weight analysis. Final R = 0.041, R_w = 0.052, S = 1.86, R for all reflections = 0.058. Maximum shift/error in final cycle 0.95. The largest residual peaks were in the region of the solvent molecule, suggesting some residual disorder and accounting for the somewhat large value of S. Computing with SHELXTL PLUS[28] on a DEC Microvax-II. Scattering factors in the analytical form and anomalous dispersion factors taken from International Tables (1974) (stored in the program). Final atomic co-ordinates including hydrogen, selected bond lengths and angles, thermal parameters and structure factors have been deposited with the Cambridge Crystallographic Centre.

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