Ortho-Metalated Primary Amines. 6.[1] The First Synthesis of Six-Membered Palladacycles from Primary Amines Containing Electron-Withdrawing Substituents: End of the Limiting Rules of Cope and Friedrich on Cyclopalladation of Benzyl- and Phenethylamines

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When $H_2N(CH_2)_2C_6H_4OMe$-4 (RNH_2) and $Pd(OAc)_2$ are reacted in a 2:1 molar ratio, the complex $[Pd(OAc)_2(NH_2R)_2]$ (**1**) is obtained. Complex **1** reacts with 1 equiv of $Pd(OAc)_2$ to give the dinuclear complex $[Pd(OAc)(\mu\text{-}OAc)(NH_2R)]_2$ (**2**). When complex **2** is heated in acetonitrile at 80 °C, the ortho-metalated complex $[Pd\{C_6H_3(CH_2)_2NH_2\text{-}2\text{-}OMe\text{-}5\text{-}\kappa^2C,N\}(\mu\text{-}OAc)]_2$ (**3a**) is obtained. Complex **3a** is also prepared by refluxing RNH_2 and $Pd(OAc)_2$ in a 1:1 molar ratio in acetonitrile. Complex **3a** reacts with NaBr or LiCl to afford the complexes $[Pd\{C_6H_3(CH_2)_2NH_2\text{-}2\text{-}OMe\text{-}5\text{-}\kappa^2C,N\}(\mu\text{-}X)]_2$ (X = Cl (**3b**), Br (**3c**)). PPh_3 splits the acetate or halide bridge in complex **3a** or **3b** to give $[Pd\{C_6H_3(CH_2)_2NH_2\text{-}2\text{-}OMe\text{-}5\text{-}\kappa^2C,N\}X(PPh_3)]$ (X = OAc (**4a**), Cl (**4b**)). With other 2-(phenyl)ethylamines or the corresponding chlorhydrates, $Pd(OAc)_2$, and PPh_3 as starting materials (molar ratio 1:1:1), the complexes $[Pd\{C_6H_3(CH_2)_2\text{-}NH_2\text{-}2\text{-}X\text{-}5\text{-}\kappa^2C,N\}Y(PPh_3)]$ (Y = OAc, X = Cl (**5**), F (**6**); Y = Cl, X = NO_2 (**7**)) have been isolated and fully characterized. These compounds include the first six-membered palladacycles synthesized from primary phenethylamines with electron-withdrawing substituents on the aryl ring. The crystal structures of **3a** and **5** have been determined by X-ray diffraction.

Introduction

The ortho-palladation of aliphatic amines was initially reported by Cope and Friedrich to fail (a) when primary amines were used, (b) when electron-withdrawing substituents were present on the aromatic ring, or (c) when a six-membered ring was to be formed.[2] These rules have been partially broken, and thus it has been proved that primary benzylamines can be ortho-metalated[3−7] even if they have electron-withdrawing groups on the aromatic ring.[4,5] Similarly, 2-phenylethylamine (phenethylamine) can also be ortho-metalated, despite being a primary amine leading to a cyclopalladated six-membered ring complex.[5] We have reported three general synthetic methods to achieve these ortho-metalation reactions.[5] In this paper, we further show the general application of these three methods to prepare ortho-metalated primary phenethylamines with electron-releasing and electron-withdrawing groups on the aromatic ring leading to complexes containing six-membered palladacycles, infringing in some cases and for the first time the three limiting rules of Cope and Friedrich[2] at once.

Results and Discussion

Synthesis of Complexes. When $H_2N(CH_2)_2C_6H_4$-OMe-4 (RNH_2) and $Pd(OAc)_2$ were reacted in a 2:1 molar ratio, the complex $[Pd(OAc)_2(NH_2R)_2]$ (**1**) was obtained (Scheme 1). Complex **1** reacted with 1 equiv of $Pd(OAc)_2$

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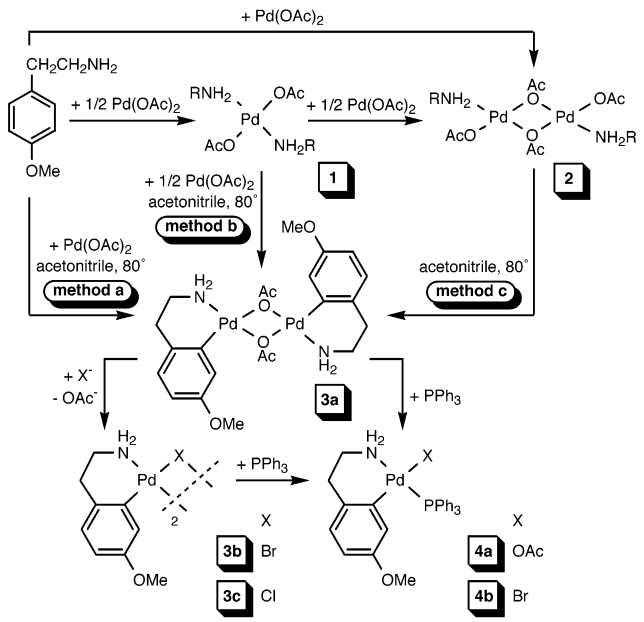
Scheme 1

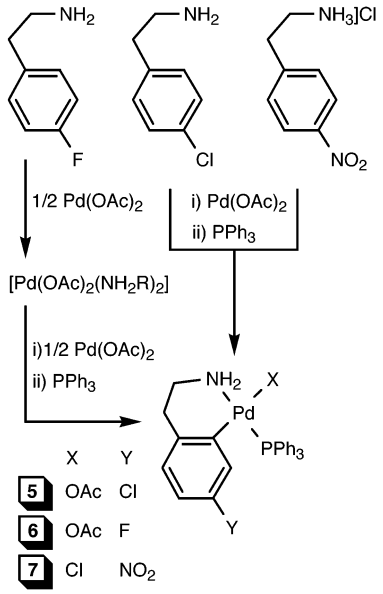


to give the dinuclear complex $[Pd(OAc)(\mu\text{-}OAc)(NH_2R)]_2$ (**2**). Complex **2** can also be prepared by reacting $H_2N(CH_2)_2C_6H_4OMe$-4 and $Pd(OAc)_2$ in a 1:1 molar ratio. The ortho-metalated complex $[Pd\{C_6H_3(CH_2)_2NH_2\text{-}2\text{-}OMe\text{-}5\text{-}\kappa^2C,N\}(\mu\text{-}OAc)]_2$ (**3a**) was obtained by the three methods we previously reported:[5] by heating at 80 °C in acetonitrile (a) $H_2N(CH_2)_2C_6H_4OMe$-4 and $Pd(OAc)_2$ in a 1:1 molar ratio, (b) $[Pd(OAc)_2(NH_2R)_2]$ (**1**) and $Pd(OAc)_2$ in a 1:1 molar ratio, or (c) complex **2** (Scheme 1). All these reactions occur with some decomposition to metallic palladium. When the reaction between the free amine and $Pd(OAc)_2$ (molar ratio 1:1) was carried out in acetonitrile at room temperature, complexes **1** and **2** could be isolated, if the reaction mixture was worked up after 10 min (complex **1**) or 40 min (complex **2**). Therefore, these complexes could be intermediates in the ortho-metalation reaction. We propose for these reactions the same mechanism that was previously reported for primary benzylamines.[5,7,8]

Complex **3a** reacts with NaBr or LiCl to afford the dinuclear complexes **3b** and **3c**, where the bridging acetate groups have been substituted by chloride or bromide anions. Triphenylphosphine splits the acetate or halide bridge in complexes **3a** and **3b** to give the mononuclear complexes **4a** and **4b** (Scheme 1). The reaction of complex **4b** with 1 equiv of PPh_3 was carried out, and the starting material was recovered.

Ortho-palladation of $H_2N(CH_2)_2C_6H_4X$-4 (X = Cl, F) can be also achieved by following method a (Scheme 2). Although the dinuclear cyclopalladated acetato-bridged complexes could not be isolated in pure form by fractional crystallization methods, the addition of PPh_3 to solutions of the crude products led to bridge splitting, and compounds $[Pd\{C_6H_3(CH_2)_2NH_2\text{-}2\text{-}Cl\text{-}5\text{-}\kappa^2C,N\}(OAc)(PPh_3)]$ (**5**) and $[Pd\{C_6H_3(CH_2)_2NH_2\text{-}2\text{-}F\text{-}5\text{-}\kappa^2C,N\}(OAc)(PPh_3)]$ (**6**) were obtained. Nevertheless, as $H_2N(CH_2)_2C_6H_4F$-4 is air sensitive, the ortho-metalation of this amine was better achieved using the starting materials $[Pd(OAc)_2\{H_2N(CH_2)_2C_6H_4F\text{-}4\}_2]$ and $Pd(OAc)_2$ (method b).

Scheme 2



As we were successfully increasing the electron-withdrawing nature of the para substituent on the aryl ring, we tried to ortho-palladate $NH_2CH_2CH_2C_6H_4NO_2$-4. As this amine is not commercially available, we used $[H_3N(CH_2)_2C_6H_4NO_2\text{-}4]Cl$ as starting material (Scheme 2). The reaction between the hydrochloride and $Pd(OAc)_2$ in acetonitrile at 80 °C was not complete, and the ortho-metalated product was contaminated with $[PdCl_2(amine)_2]$, as proved by ^1H NMR. Although they could not be separated by fractional crystallization methods, reaction with PPh_3 in acetone or CH_2Cl_2 led to $[PdCl_2(PPh_3)_2]$ (insoluble in both solvents) and $[Pd\{C_6H_3(CH_2)_2NH_2\text{-}2\text{-}NO_2\text{-}5\text{-}\kappa^2C,N\}Cl(PPh_3)]$ (**7**).

Structure of Complexes. ^1H and ^{13}C NMR of complex **1** indicated that only the cis or trans isomer was obtained, because only one set of signals appeared. We assumed a trans geometry because it must be the thermodynamically most stable form, as proved for bis(amine)dihalogenopalladium(II) complexes.[9] ^1H and ^{13}C NMR spectra of complex **2** showed only two signals for the acetate methyl groups: one for the pair of bridging acetates and another for the pair of terminal acetates. Thus, the latter must have the same chemical environment and must adopt a trans disposition.

The crystal structure of complex $\mathbf{3a}\cdot{}^3/_8CH_2Cl_2$ has been determined by X-ray diffraction studies (Figure 1). The structure shows two independent dinuclear molecules in the asymmetric unit. Each palladium center is in a slightly distorted square-planar coordination mode (mean deviation range of the plane 0.02−0.04 Å). The bridging acetate groups force the two palladium planes of each dimer to have dihedral angles of 35.0(1) and 37.1(1)°, adopting a nonplanar open-book shape. The chelated amino ligand forms a six-membered metallacycle, being the first intermediate of this type characterized by X-ray diffraction. The six-membered metallacycles are in a boat conformation for both independent molecules. In the crystal, N−H···O hydro-

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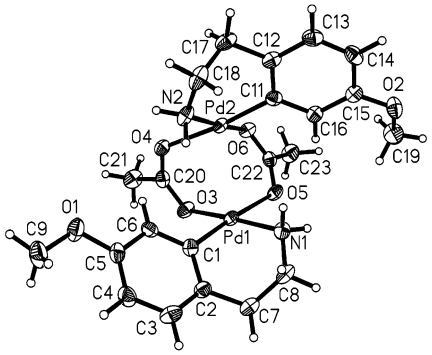

Figure 1. Thermal ellipsoid plot (50% probability) of a dimer of **3a**, along with the labeling scheme (same labeling scheme plus an "A" for the other dimer). Selected bond lengths (Å) and angles (deg): Pd(1)−C(1) = 1.969(6), Pd(1)−N(1) = 2.049(5), Pd(1)−O(3) = 2.067(4), Pd(1)−O(5) = 2.177(4), Pd(1)···Pd(2) = 2.9229(7), Pd(2)−C(11) = 1.965(6), Pd(2)−O(6) = 2.055(4), Pd(2)−N(2) = 2.059(5), Pd(2)−O(4) = 2.185(4), Pd(1A)−C(1A) = 1.969(6), Pd(1A)−N(1A) = 2.052(5), Pd(1A)−O(3A) = 2.057(4), Pd(1A)−O(5A) = 2.170(4), Pd(1A)···Pd(2A) = 2.9719(7), Pd(2A)−C(11A) = 1.973(6), Pd(2A)−N(2A) = 2.037(5), Pd(2A)−O(6A) = 2.062(4), Pd(2A)−O(4A) = 2.182(4); C(1)−Pd(1)−N(1) = 88.8(2), C(1)−Pd(1)−O(3) = 92.7(2), N(1)−Pd(1)−O(5) = 89.70(17), O(3)−Pd(1)−O(5) = 88.49(16), C(11)−Pd(2)−O(6) = 90.5(2), C(11)−Pd(2)−N(2) = 92.3(2), O(6)−Pd(2)−O(4) = 88.55(15), N(2)−Pd(2)−O(4) = 88.10(17), C(1A)−Pd(1A)−N(1A) = 89.8(2), C(1A)−Pd(1A)−O(3A) = 91.4(2), N(1A)−Pd(1A)−O(5A) = 86.65(17), O(3A)−Pd(1A)−O(5A) = 91.88(16), C(11A)−Pd(2A)−N(2A) = 91.7(2), C(11A)−Pd(2A)−O(6A) = 89.76(19), N(2A)−Pd(2A)−O(4A) = 85.63(17) and O(6A)−Pd(2A)−O(4A) = 92.17(15).

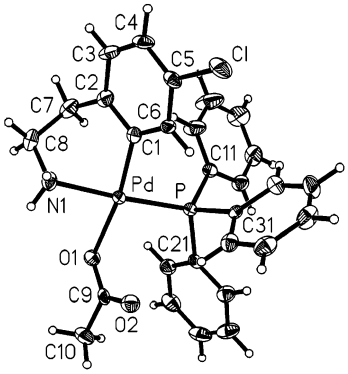

Figure 2. Thermal ellipsoid plot (50% probability) of **5**, along with the labeling scheme. Selected bond lengths (Å) and angles (deg): Pd−C(1) = 1.998(5), Pd−O(1) = 2.101(3), Pd−N(1) = 2.111(4), Pd−P = 2.2518(13); C(1)−Pd−N(1) = 84.29(17), O(1)−Pd−N(1) = 85.68(14), C(1)−Pd−P = 93.85(13), O(1)−Pd−P = 96.18(9).

gen bonds form zigzag chains parallel to the *b* axis (see the Supporting Information).

The crystal structure of complex **5** (Figure 2) shows the phosphine ligand trans to the amine group, demonstrating once again the well-established tendency of PPh_3 and aryl ligands not to be trans to each other when coordinated to palladium. We have proposed for this destabilizing effect between pairs of trans ligands in palladium complexes the term of *transphobia*.[10] This term has also been used by other authors.[11] The six-membered metallacycle in complex **5** shows a boat conformation and a slightly distorted square-planar geometry (N−Pd−C and Br−Pd−P dihedral angle of 4.3°). Intermolecular N−H···O hydrogen bonds are also observed. The proposed structures for complexes **4a,b**, **6**, and **7** are based on the crystal structure of complex **5** and on those of related complexes, as well as on the P/C transphobia.

Ortho-metalation is also evident from the study of the ^1H and ^{13}C NMR spectra of complexes **3**−**7**. The AB system characteristic of meta and ortho aromatic protons of para-disubstituted aryl groups of the amines changes into a set of three different signals, corresponding to H(3), H(4), and H(6) of the ortho-metalated ring. In complex **7**, the H(4) and H(6) resonances are not observed because they appear in the multiplet corresponding to the phenyl groups. On the other hand, the resonance due to carbon C(1) shifts downfield with respect to the non-ortho-metalated group.

In conclusion, we have shown that it is possible to cyclopalladate primary phenethylamines with electron-withdrawing groups, infringing, for the first time, the three limiting rules of Cope and Friedrich on cyclopalladation of benzyl- and phenethylamines. This is THE END of the issue.

Experimental Section

General Procedures. Infrared spectra were recorded on Perkin-Elmer 1430 and 16F-PC-FT spectrometers. C, H, and N analyses, conductance measurements, and melting point determinations were carried out as described elsewhere.[3,4] Unless otherwise stated, NMR spectra were recorded in $CDCl_3$, with Varian Unity 300 and Bruker AC-400 spectrometers. Chemical shifts are referenced to TMS (^1H and $^{13}C\{^1H\}$) or H_3PO_4 ($^{31}P\{^1H\}$). Signals in the ^1H and ^{13}C NMR spectra of complexes **1**, **3a**, and **4a** were assigned with the help of HSQC and HMBC techniques. $^{13}C\{^1H\}$ NMR data for complexes **3b** and **5**−**7** have been included in the Supporting Information. Reactions were carried out at room temperature without special precautions against moisture. The molar conductivities of all complexes in acetone are between 0 and 1 Ω^{-1} cm^2 mol^{-1}, in agreement with their nonelectrolytic nature.[12] 4-Methoxyphenethylamine, 4-chlorophenethylamine, 4-fluorophenethylamine, and 4-nitrophenethylamine hydrochloride (Aldrich) and palladium acetate (Johnson Mattey) were used as received.

Synthesis of $[Pd(OAc)_2\{NH_2(CH_2)_2C_6H_4OMe\text{-}4\}_2]$ (1). To a suspension of $Pd(OAc)_2$ (307 mg, 1.37 mmol) in acetone (10 mL) was added 4-methoxyphenethylamine (0.400 mL, 2.74 mmol), and the resulting mixture was stirred for 1 h. A yellow solid precipitated, which was filtered, washed with Et_2O, and

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air-dried to afford complex **1**. Yield: 625 mg, 87%. Mp: 156 °C. Anal. Calcd for $C_{22}H_{32}N_2O_6Pd$: C, 50.15; H, 6.13; N, 5.34. Found: C, 50.04; H, 6.12; N, 5.32. ^{1}H NMR (400 MHz): δ 1.86 (s, 3 H, *Me*CO_2), 2.77 (quint, 2 H, *CH*$_2$NH$_2$), 2.94 ("t", 2 H, *CH*$_2$-Ar), 3.69 (m, 2 H, NH$_2$), 3.78 (s, 3 H, OMe), 6.84 and 7.12 (AB system, 4 H, C_6H_4, $^3J_{AB}$ = 8.6 Hz). ^{13}C{^{1}H} NMR (400 MHz): δ 23.4 (s, *Me*CO_2), 36.0 (s, *C*H$_2$Ar), 44.8 (s, *C*H$_2$NH$_2$), 55.2 (s, OMe), 114.1 (s, *m*-CH, C_6H_4), 129.5 (s, ipso *C*−CH$_2$), 129.7 (s, *o*-CH, C_6H_4), 158.4 (s, ipso *C*-OMe), 179.9 (s, Me*C*O$_2$).

Synthesis of [Pd{μ-(OAc)}(OAc){NH$_2$(CH$_2$)$_2$C$_6$H$_4$OMe-4}]$_2$ (2). To a suspension of Pd(OAc)$_2$ (213 mg, 0.949 mmol) in CH_2Cl_2 (25 mL) was added [Pd(OAc)$_2${NH$_2$(CH$_2$)$_2$C$_6$H$_4$OMe-4}$_2$] (**1**; 501 mg, 0.951 mmol). The mixture was stirred at room temperature for 20 h. The resulting solution was filtered through a plug of $MgSO_4$, the solvent removed, the residue taken up in acetone (1 mL), and the resulting solution slowly dropped over stirred *n*-pentane (40 mL). An orange solid precipitated, which was filtered, washed with *n*-pentane, and air-dried to afford complex **2**. Yield: 429 mg, 59%. Mp: 67 °C. Anal. Calcd for $C_{26}H_{38}N_2O_{10}Pd_2$: C, 41.56; H, 5.10; N, 3.73. Found: C, 41.66; H, 5.29; N, 3.88. ^{1}H NMR: δ 1.88 (s, 3 H, *Me*CO_2), 1.89 (s, 3 H, *Me*CO_2), 2.51 (m, 1 H, CH$_2$), 2.67 (m, 1 H, CH$_2$), 3.18 (m, 2 H, CH$_2$), 3.71 (br s, 1 H, NH$_2$), 3.79 (s, 3 H, OMe), 5.09 (br s, 1 H, NH$_2$), 7.84, 7.13 (AB system, 4 H, C_6H_4, $^3J_{AB}$ = 8.4 Hz). ^{13}C{^{1}H} NMR: δ 23.0 (s, *Me*CO_2), 23.1 (s, MeCO_2), 35.4 (s, CH$_2$), 44.8 (s, CH$_2$), 55.3 (s, OMe), 114.1 (s, *m*-CH, C_6H_4), 129.6 (s, ipso *C*−CH$_2$), 129.6 (s, *o*-CH, C_6H_4), 158.5 (s, ipso *C*−OMe), 179.7 (s, terminal Me*C*O$_2$), 185.6 (s, μ-Me*C*O$_2$). Complex **2** can be prepared by reacting Pd(OAc)$_2$ and the free amine in CH_2Cl_2 (molar ratio 1:1) with similar yield.

Synthesis of [Pd{C$_6$H$_3$(CH$_2$)$_2$NH$_2$-2-OMe-5-κ^2*C,N*}(μ-OAc)]$_2$ (3a). 4-Methoxyphenethylamine (0.300 mL, 2.06 mmol) and Pd(OAc)$_2$ (463 mg, 2.06 mmol) were refluxed in acetonitrile (25 mL) for 4 h. The resulting suspension was filtered through a plug of $MgSO_4$, the solvent evaporated to dryness, and the residue collected with acetone, filtered, and air-dried to afford complex **3a** as a dark yellow solid. Yield: 171 mg, 26%. Mp: 160 °C dec. Anal. Calcd for $C_{22}H_{30}N_2O_6Pd_2$: C, 41.86; H, 4.79; N, 4.44. Found: C, 41.58; H, 4.84; N, 4.08. ^{1}H NMR (400 MHz): δ 2.02 (s, 3 H, *Me*CO_2), 2.22 (m, 1 H, C*H*$_2$NH$_2$), 2.33 (m, 1 H, C*H*$_2$NH$_2$), 2.50 (m, 1 H, C*H*$_2$Ar), 2.71 (m, 1 H, C*H*$_2$-Ar), 3.02 (br s, 1 H, NH$_2$), 3.36 (br s, 1 H, NH$_2$), 3.73 (s, 3 H, OMe), 6.49 (dd, 1 H, H4, C_6H_3, $^3J_{HH}$ = 8.1, $^4J_{HH}$ = 2.6 Hz), 6.67 (d, 1 H, H6, C_6H_3, $^4J_{HH}$ = 3 Hz), 6.71 (d, 1 H, H3, C_6H_3, $^3J_{HH}$ = 8.1 Hz). ^{13}C{^{1}H} NMR (400 MHz): δ 24.4 (s, *Me*CO_2), 39.4 (s, *C*H$_2$Ar), 40.3 (s, *C*H$_2$NH$_2$), 55.1 (s, OMe), 109.5 (s, C4, C_6H_3), 118.3 (s, C6, C_6H_3), 127.0 (s, C3, C_6H_3), 130.4 (s, C2, C_6H_3), 137.4 (s, C1, C_6H_3), 155.5 (s, C5, C_6H_3), 181.2 (s, Me*C*O$_2$).

Synthesis of [Pd{C$_6$H$_3$(CH$_2$)$_2$NH$_2$-2-OMe-5-κ^2*C,N*}(μ-Br)]$_2$ (3b). To a suspension of complex **3a** (350 mg, 0.554 mmol) in acetone (35 mL) was added solid NaBr (1140 mg, 11.08 mmol), and the mixture was stirred for 8 h. The solvent was removed and CH_2Cl_2 (25 mL) added. The resulting suspension was filtered through a plug of $MgSO_4$ and concentrated to ca. 2 mL and Et$_2$O (10 mL) added to precipitate a yellow solid, which was filtered, washed with Et$_2$O, and air-dried to afford complex **3b**. Yield: 285 mg, 77%. Mp: 199 °C. Anal. Calcd for $C_{18}H_{24}Br_2N_2O_2Pd_2$: C, 32.12; H, 3.59; N, 4.16. Found: C, 32.31; H, 3.50; N, 4.09. ^{1}H NMR: δ 2.48 (m, 2 H, CH$_2$), 2.92 ("t", 2 H, CH$_2$), 3.64 (s, 3 H, OMe), 4.06 (br s, 2 H, NH$_2$), 6.38 (dd, 1 H, H4, C_6H_3, $^3J_{HH}$ = 8.1, $^4J_{HH}$ = 2.7 Hz), 6.67 (d, 1 H, H3, C_6H_3, $^3J_{HH}$ = 8.1 Hz), 6.91 (d, 1 H, H6, C_6H_3, $^4J_{HH}$ = 2.7 Hz).

Synthesis of [Pd{C$_6$H$_3$(CH$_2$)$_2$NH$_2$-2-OMe-5-κ^2*C,N*}(μ-Cl)]$_2$ (3c). Complex **3c** was prepared as a pale yellow solid in a way similar to that for complex **3b**, starting from complex **3a** (503 mg, 0.797 mmol) and solid LiCl (676 mg, 15.9 mmol). The reaction mixture was stirred for 20 h. Yield: 300 mg, 64%. Mp: 141 °C. Anal. Calcd for $C_{18}H_{24}Cl_2N_2O_2Pd_2$: C, 37.01; H, 4.14; N, 4,80. Found: C, 37.26; H, 4,11; N, 4.90. ^{1}H NMR: δ 2.44 (m, 2 H, CH$_2$), 2.87 ("t", 2 H, CH$_2$), 3.67 (s, 3 H, OMe), 4.30 (br s, 2 H, NH$_2$), 6.41 (dd, 1 H, H4, C_6H_3, $^3J_{HH}$ = 8.1, $^4J_{HH}$ = 2.7 Hz), 6.70 (d, 1 H, H3, C_6H_3, $^3J_{HH}$ = 8.1 Hz), 6.84 (d, 1 H, H6, C_6H_3, $^4J_{HH}$ = 2.7 Hz).

Synthesis of [Pd{C$_6$H$_3$(CH$_2$)$_2$NH$_2$-2-OMe-5-κ^2*C,N*}(OAc)(PPh$_3$)] (4a). To a suspension of complex **3a** (114 mg, 0.181 mmol) in CH_2Cl_2 (30 mL) was added solid PPh$_3$ (95 mg, 0.36 mmol). After the mixture was stirred for 6 h, a colorless solution formed, which was filtered through a plug of $MgSO_4$ and concentrated to ca. 2 mL. Et$_2$O (20 mL) was added to precipitate a pale yellow solid, which was filtered, washed with Et$_2$O, and air-dried to afford complex **4a**. Yield: 161 mg, 78%. Mp: 180 °C. Anal. Calcd for $C_{29}H_{30}NO_3PPd$: C, 60.27; H, 5.23; N, 2.42. Found: C, 60.17; H, 5.23; N, 2.41. ^{1}H NMR (400 MHz): δ 1.47 (s, 3 H, *Me*CO_2), 2.72 (br s, 2 H, *CH*$_2$NH$_2$), 3.10 (s, 3 H, MeO), 3.16 ("t", 2 H, *CH*$_2$Ar), 4.20 (br s, 2 H, NH$_2$), 6.06 (dd, 1 H, H6, C_6H_3, $^4J_{HH}$ = 2.5, $^4J_{PH}$ = 5.1 Hz), 6.37 (dd, 1 H, H4, C_6H_3, $^3J_{HH}$ = 8.0, $^4J_{HH}$ = 2.5 Hz), 6.83 (d, 1 H, H3, C_6H_3, $^3J_{HH}$ = 8.1 Hz), 7.30−7.52 (m, 15 H, PPh$_3$). ^{13}C{^{1}H} NMR (400 MHz): δ 24.2 (s, *Me*CO_2), 37.8 (d, *CH*$_2$NH$_2$, $^3J_{PC}$ = 2.1 Hz), 42.8 (s, *CH*$_2$Ar), 54.4 (s, OMe), 110.7 (s, C4, C_6H_3), 120.5 (d, C6, C_6H_3, $^3J_{PC}$ = 11.5 Hz), 126.4 (s, C3, C_6H_3), 128.2 (d, *m*-CH, PPh$_3$, $^3J_{PC}$ = 10.6 Hz), 130.2 (d, *p*-CH, PPh$_3$, $^4J_{PC}$ = 2.3 Hz), 130.4 (d, ipso C, PPh$_3$, $^1J_{PC}$ = 48.3 Hz), 132.5 (s, C2, C_6H_3), 134.5 (d, *o*-CH, PPh$_3$, $^2J_{PC}$ = 11.7 Hz), 146.2 (d, C1, C_6H_3, $^2J_{PC}$ = 2.7 Hz), 155.5 (d, C5, C_6H_3, $^4J_{PC}$ = 4.4 Hz), 178.9 (s, Me*C*O$_2$). ^{31}P{^{1}H} NMR: δ 33.2 (s).

Synthesis of [Pd{C$_6$H$_3$(CH$_2$)$_2$NH$_2$-2-OMe-5-κ^2*C,N*}Br(PPh$_3$)] (4b). Complex **4b** was prepared as an yellow ocher solid in a way similar to that for complex **4a**, starting from complex **3b** (132 mg, 0.196 mmol) and solid PPh$_3$ (103 mg, 0.392 mmol), and the mixture was stirred for 5 h. Yield: 204 mg, 87%. Mp: 155 °C. Anal. Calcd for $C_{27}H_{27}BrNOPPd$: C, 54.16; H, 4.55; N, 2.34. Found: C, 54.15; H, 4.41; N, 2.00. ^{1}H NMR: δ 2.77 (br s, 2 H, CH$_2$), 3.14 ("t", 2 H, CH$_2$), 3.20 (s, 3 H, OMe), 3.37 (br s, 2 H, NH$_2$), 6.06 (dd, 1H, H6, C_6H_3, $^4J_{HH}$ = 2.7, $^4J_{PH}$ = 5.4 Hz), 6.35 (dd, 1 H, H4, C_6H_3, $^3J_{HH}$ = 8.1, $^4J_{HH}$ = 2.7 Hz), 6.79 (d, 1 H, H3, C_6H_3, $^3J_{HH}$ = 8.1 Hz), 7.24−7.56 (m, 15 H, PPh$_3$). ^{31}P{^{1}H} NMR: δ 34.3 (s).

Synthesis of [Pd{C$_6$H$_3$(CH$_2$)$_2$NH$_2$-2-Cl-5-κ^2*C,N*}(OAc)(PPh$_3$)] (5). 4-Chlorophenethylamine (0.300 mL, 2.14 mmol) and Pd(OAc)$_2$ (481 mg, 2.14 mmol) were refluxed in acetonitrile (40 mL) for 4 h. The resulting suspension was filtered through a plug of $MgSO_4$ and the filtrate concentrated to dryness. The residue was dissolved in CH_2Cl_2 (5 mL) and an Et$_2$O/*n*-hexane mixture added (1:1, 30 mL) to precipitate a brown solid (502 mg). To a solution of this solid (100 mg, 0.156 mmol) in acetone (10 mL) was added solid PPh$_3$ (82 mg, 0.313 mmol). After the mixture was stirred for 30 min, a pale yellow solid precipitated, which was filtered, washed with Et$_2$O, and air-dried to afford complex **5**. Yield: 84 mg, 46%. Dec pt: 155 °C. Anal. Calcd for $C_{28}H_{27}ClNO_2PPd$: C, 57.75; H, 4.67; N, 2.40. Found: C, 57.64; H, 4.65; N, 2.34. ^{1}H NMR: δ 1.53 (s, 3 H, *Me*CO_2), 2.73 (br s, 2 H, CH$_2$), 3.17 ("t", 2 H, CH$_2$), 4.41 (br s, 2 H, NH$_2$), 6.29 (dd, 1 H, H6, C_6H_3, $^4J_{HH}$ = 2.1, $^4J_{PH}$ = 4.5 Hz), 6.73 (dd, 1 H, H4, C_6H_3, $^3J_{HH}$ = 8.1, $^4J_{HH}$ = 2.0 Hz), 6.79 (d, 1 H, H3, C_6H_3, $^3J_{HH}$ = 8.1 Hz), 7.26−7.54 (m, 15 H, Ph). ^{31}P{^{1}H} NMR: δ 32.5 (s).

Synthesis of [Pd{C$_6$H$_3$(CH$_2$)$_2$NH$_2$-2-F-5-κ^2*C,N*}(OAc)(PPh$_3$)] (6). [Pd(OAc)$_2$(NH$_2$CH$_2$C$_6$H$_4$F-4)$_2$] (500 mg, 0.994 mmol) and Pd(OAc)$_2$ (223 mg, 0.99 mmol) were refluxed in acetonitrile (40 mL) for 4 h. The resulting suspension was filtered through a plug of $MgSO_4$ and the filtrate concentrated to dryness. The residue was dissolved in CH_2Cl_2 (5 mL) and an Et$_2$O/*n*-hexane mixture (1:1, 30 mL) added to precipitate a brown solid (340 mg). To a solution of this solid (125 mg, 0.21 mmol) in acetone (5 mL) was added solid PPh$_3$ (108 mg, 0.41 mmol). After the mixture was stirred for 30 min, a pale yellow solid precipitated, which was filtered, washed with Et$_2$O, and air-dried to afford complex **6**. Yield: 68 mg, 30%. Mp: 156 °C

dec. Anal. Calcd for $C_{28}H_{27}FNO_2PPd$: C, 59.43; H, 4.81; N, 2.46. Found: C, 59.28; H, 4.78; N, 2.50. ^{1}H NMR: δ 1.52 (s, 3 H, Me), 2.74 (m, 2 H, CH_2), 3.19 ("t", 2 H, CH_2), 4.32 (br s, 2 H, NH_2), 6.08 (ddd, 1 H, H6, $^3J_{FH} = 7.2$, $^4J_{PH} = 4.5$, $^4J_{HH} = 2.5$ Hz), 6.46 (dt, 1 H, H4, $^3J_{HH} = {}^3J_{FH} = 8.4$, $^4J_{HH} = 2.5$ Hz), 6.83 (dd, 1 H, H3, $^3J_{HH} = 8.1$, $^4J_{FH} = 5.8$ Hz), 7.29−7.55 (m, 15 H, Ph). ^{31}P{^{1}H} NMR: δ 32.6 (s).

Synthesis of [Pd{$C_6H_3(CH_2)_2NH_2$-2-NO_2-5-κ^2C,N}Cl-(PPh_3)] (7). 4-Nitrophenethylamine−HCl (500 mg, 2.47 mmol) and $Pd(OAc)_2$ (554 mg, 2.47 mmol) were refluxed in acetonitrile (40 mL) for 16 h. The resulting brown suspension was filtered through a plug of $MgSO_4$, the solvent removed, and CH_2Cl_2 added (20 mL). A brown solid was formed (353 mg) whose ^{1}H NMR in acetone-d_6 corresponded to a mixture of ortho-metalated complex and [$PdCl_2$(amine)$_2$]. To a suspension of this solid (100 mg) in CH_2Cl_2 (20 mL) was added PPh_3 (90 mg, 0.34 mmol). After the mixture was stirred for 30 min, a brown solution formed which was filtered through a plug of $MgSO_4$ and concentrated to ca. 1 mL. A yellow solid (50 mg, 0.98 mmol, 30%) precipitated that proved to be [$PdCl_2(PPh_3)$] by ^{1}H NMR analysis. Et_2O/*n*-hexane mixture (1:1,15 mL) was added to the mother liquor and a dark yellow solid precipitated, which was filtered, washed with *n*-hexane, and air-dried to afford complex **7**. Yield: 69 mg, 37%. Mp: 126 °C. Anal. Calcd for $C_{26}H_{24}ClN_2O_2PPd$: C, 54.85; H, 4.25; N, 4.92. Found: C, 55.18; H, 4.21; N, 4.60. ^{1}H NMR: δ 2.61 (m, 2 H, CH_2), 3.22 (m, 2 H, CH_2), 3.50 (m, 2 H, NH_2), 6.93 (d, 1 H, H3, $^3J_{HH} = 8.1$ Hz), 7.24−7.62 (m, 17 H, Ph + H4 + H6). ^{31}P{^{1}H} NMR: δ 33.6 (s).

X-ray Structure Determinations. Crystals of **3a**·$^3/_8CH_2Cl_2$ and **5** suitable for X-ray diffraction were measured. Structures were solved by direct methods (**3a**·$^3/_8CH_2Cl_2$) or the heavy-atom method (**5**). All non-hydrogen atoms were refined anisotropically on F^2 (program SHELXL-97, G. M. Sheldrick, University of Göttingen, Göttingen, Germany). Hydrogen atoms were included using a riding model or as rigid methyl groups. In the compound **3a**·$^3/_8CH_2Cl_2$, a poorly resolved solvent site near an inversion center was interpreted as $^1/_4$ of disordered CH_2Cl_2. The programs use neutral atom scattering factors, $\Delta f'$ and $\Delta f''$ values, and absorption coefficients from ref 13.

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Supporting Information Available: Listings of all refined and calculated atomic coordinates, anisotropic thermal parameters, and bond lengths and angles for **3a** and **5**, and ^{13}C{^{1}H} NMR data for complexes **3b** and **5**−**7**, and a figure showing the N−H···O hydrogen bonds for complex **5**; crystallographic data for **3a** and **5** are also available as CIF files. This material is available free of charge via the Internet at http://pubs.acs.org.

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