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Palladium-Catalyzed Indole, Pyrrole, and Furan Arylation by Aryl Chlorides

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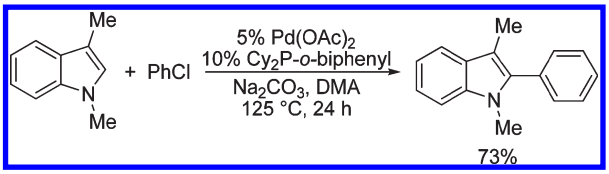

The palladium-catalyzed direct arylation of indoles, pyrroles, and furans by aryl chlorides has been demonstrated. The method employs a palladium acetate catalyst, 2-(dicyclohexylphosphino)-biphenyl ligand, and an inorganic base. Electron-rich and electron-poor aryl chlorides as well as chloropyridine coupling partners can be used, and arylated heterocycles are obtained in moderate to good yields. Optimization of base, ligand, and solvent is required for achieving best results.

Introduction

The aryl-heteroaryl bond is common in organic materials, bioactive molecules, and pharmaceuticals.[1] Consequently, formation of such bonds has been the focus of intensive research. Methods that have been developed for creation of aryl-heteroaryl linkages are summarized in Scheme 1. One can couple either the aryl halide with heteroaryl metal reagent or aryl metal with heteroaryl halide (Pathway A).[2] This is the classical route for creation of sp^2-sp^2 carbon−carbon bonds. The advantages include excellent control of regioselectivity as well as extensively investigated chemistry that allows synthesis of nearly any structural motifs. A disadvantage includes the necessity to prepare functionalized starting materials, thus lengthening synthetic sequences. Coupling of an aryl halide with a heterocycle C−H bond or, rarely, arene with heteroaryl halide also can result in the formation of an arylated heterocycle (Pathway B).[3,4] In this case, one can use readily available, stable heterocycles and aryl halides, thus avoiding several synthetic steps and shortening synthetic schemes. Regioselectivity issues are

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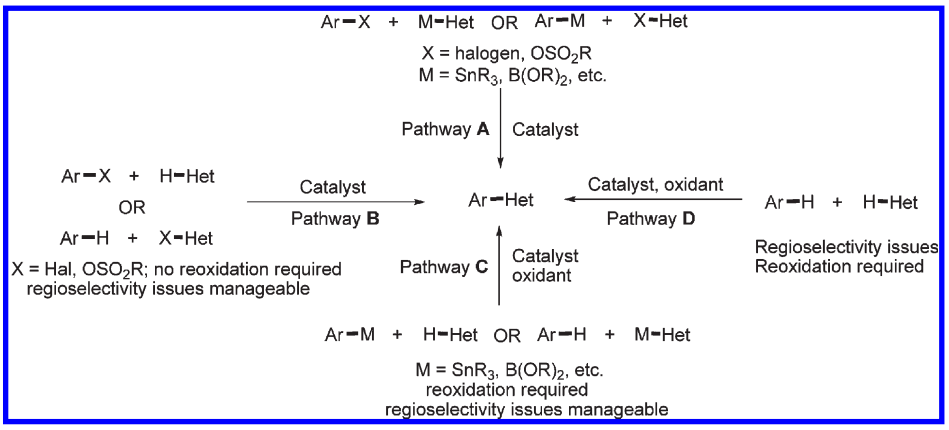
SCHEME 1. Methods for Heterocycle Arylation



manageable because most of heterocyclic C−H bond arylations are regioselective. The third possibility is the coupling of arylmetal with heterocycle or, rarely, arene with a heteroaryl metal reagent (Pathway C).[5] Carboxylates can be employed as arylmetal surrogates.[5j] Although this method allows the use of stable and readily available heterocycles as one of the coupling components, several disadvantages are obvious compared with Pathway B. First, a stoichiometric reoxidant, typically a copper or silver salt, is often required for catalytic turnover generating heavy metal waste. Second, aryl metal reagents are often prepared from aryl halides, thus increasing total number of steps to the desired product. The final possibility is the cross-coupling of heterocycle and arene C−H bonds (Pathway D).[6] Readily available arenes and heterocycles are used as the coupling partners. Consequently, Pathway D is the shortest route to the cross-coupled product since no functionalized intermediates need to be prepared. The potential problems include lack of regioselectivity with respect to simple arene coupling partners such as toluene and requirement for a stoichiometric oxidant. Additionally, a large excess of the arene component is often employed, decreasing the efficiency of the process. However, this method appears to hold the most promise if the regioselectivity problems are solved and environmentally friendly oxidants such as oxygen[7] could be employed.

The above analysis shows that methodology following either Pathway B or Pathway D should result in the most efficient arylation processes. At this point, it is not obvious how to solve the regioselectivity issues for Pathway D, although in special cases cross-coupling selectivity has been obtained by employing tailored ligands on palladium.[8] While arylations according to pathway B are common, in most cases aryl bromide or iodide reagents have been employed and the methodology appears to be mature.[3,4] In contrast, nonactivated aryl chlorides rarely have been used.[3d,e,4b,4c,4e] Curiously, a pioneering paper describing activated (electron-poor) aryl chloride use in heterocycle arylation was published in 1985 and is one of the first intermolecular direct heterocycle arylation examples.[3a] Ohta showed that chloropyrazines regioselectively arylate *NH*-indoles at the C-2 position if $Pd(PPh_3)_4$ catalyst is employed. He also showed that a copper additive improves the arylation yield, a modification that is now widely used for such reactions. The use of nonactivated aryl chlorides for intermolecular reactions was reported in 2004 when Sadighi disclosed a method for the arylation of zincated pyrroles by aryl halides.[3d] However, a general method for electron-rich heterocycle arylation was not reported until 2007 when we showed that electron-rich, bulky butyldi-1-adamantylphosphine in combination with $Pd(OAc)_2$ effects the arylation of a wide variety of five-membered ring heterocycles such as thiophene, benzothiophene, 1,2- and 1,3-oxazole derivatives, benzofuran, thiazoles, benzothiazole, 1-alkylimidazoles, 1-alkyl-1,2,4-triazoles, and caffeine. Electron-rich, electron-poor, and heteroaryl chlorides can be used.[3e] However, indoles, furans, and pyrroles were not arylated effectively. Low conversions and/or regioisomer mixtures were obtained. Several recent reports from other groups describe use of nonactivated aryl chlorides in heterocycle C−H bond arylations.[4b,c,e] However, *N*-substituted indole, pyrrole, and furan arylation by nonactivated aryl chlorides has been elusive. We report here a method for *N*-substituted indole and pyrrole as well as furan arylation by aryl chlorides. A catalyst system consisting of a combination of bulky Buchwald phosphine ligands with palladium(II) acetate and an inorganic base is employed in most cases.

Results and Discussion

1. Indole Arylation. Aryl bromides and iodides have been used extensively in palladium-catalyzed direct indole

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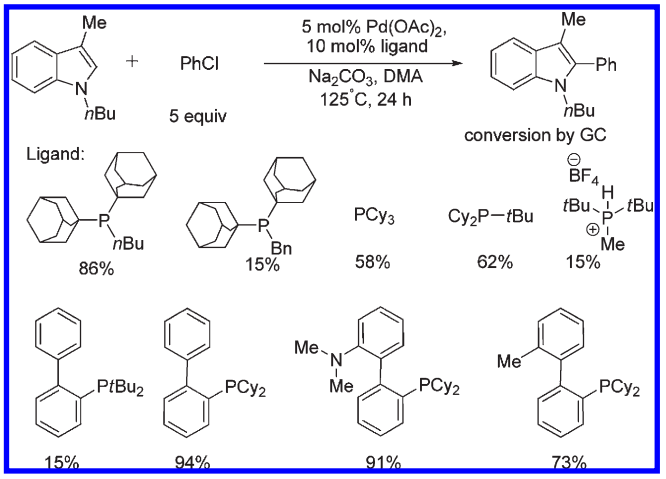
SCHEME 2. Ligand Screening for Coupling of 1-Butyl-3-methylindole with Chlorobenzene



arylations.[3g−o] However, only a few examples of activated aryl chloride use have been reported.[3a] Our previously reported reaction conditions resulted in incomplete conversions for substituted indole C-arylation.[3e] Consequently, reaction conditions were optimized in the arylation of 1-butyl-3-methylindole by chlorobenzene. A short screening with respect to base and solvent showed that highest conversions are obtained by employing dimethylacetamide in combination with sodium carbonate. During previous studies for the coupling of electron-rich heterocycles with aryl chlorides it was discovered that secondary phosphine oxides and *N*-heterocyclic carbene (NHC) ligands are not effective in promoting the desired reaction.[3e] Therefore, the present evaluation mainly focused on electron-rich trialkyl phosphine ligands since they are known to promote oxidative addition of aryl chlorides to Pd(0).[9] Only commercially available ligands were screened. Di-*tert*-butyl(methyl)-phosphonium tetrafluoroborate afforded low conversion to the desired product (Scheme 2). Surprisingly, structurally similar ligands such as butyldi-1-adamantylphosphine and benzyldi-1-adamantylphosphine demonstrated different results, with the former one being much more effective. Similarly, structurally related Buchwald phosphines[10] afforded variable conversions depending on the substitution pattern. Ligands containing two *tert*-butyl groups on the phosphorus atom generally showed lower conversions to the arylated product, in contrast with the report by Sadighi.[3d] Ligands possessing two cyclohexyl substituents on the phosphorus atom demonstrated good efficiency. Reasonable conversions were also observed if tricyclohexylphosphine and *tert*-butyldicyclohexylphosphine were used. Out of several ligands that afforded high conversions in the arylation, 2-(dicyclohexylphosphino)biphenyl was chosen for further investigation because of its air-stable nature and cost considerations.

A number of substituted indoles can be coupled with a variety of aryl chlorides under these conditions (Table 1). 1,3-Dimethylindole reacts with aryl chlorides to give desired products in good yields (entries 1, 11−13). Some steric bulk is tolerated on indole species. 1-Butyl-3-methylindole, 3-butyl-1-methylindole, 3-methyl-1-phenylindole, 1-methyl-3-phenylindole, and 3-cyclohexyl-1-methylindole can be arylated in excellent yields (entries 2−6). It is known that activated aryl chlorides are generally more reactive in heterocycle arylation, and many examples have been described in literature.[3a,p,s,4l,4m] However, in this case both electron-rich and electron-poor aryl chlorides are reactive. Chlorobenzene, 3-chloroanisole, 5-chloro-*m*-xylene, 3-chlorotoluene, 1-chloro-3,4-dimethylbenzene, 3-chloropyridine, and 1,4-dichlorobenzene are suitable coupling partners that afford desired products in good to excellent yields. Substitution on the phenyl ring of indole is tolerated (entries 16 and 17). Previously unreactive 1,2-dimethylindole is arylated in the 3-position under the optimized conditions by employing standard reaction conditions (entry 14). The major product of the arylation of 1-methylindole is 1-methyl-2-phenylindole in addition to minor amounts of 1-methyl-3-phenylindole and 1-methyl-2,3-diphenylindole byproducts (entry 15). However, this reaction requires slightly modified reaction conditions. Butyldi-1-adamantylphosphine ligand in combination with K_3PO_4 base in NMP solvent afforded the best results.

The method fails for the following substrates. Unprotected indoles afford mostly *N*-arylated products under these conditions.[11] Arylation of indoles possessing electron-withdrawing groups on the nitrogen result in either decomposition of the starting material or low conversion to product. Silicon-containing protecting groups on the indole nitrogen are removed under these reaction conditions. Arylation of 1-*tert*-butyl-3-methylindole results in low conversion, presumably due to steric bulk.

2. Pyrrole Arylation. Arylation of pyrroles by aryl iodides and bromides has been extensively investigated.[3k,s,t] However, only a few examples of aryl chloride use have been reported, most notably in the work by Sadighi where three examples of *N*-zincated pyrrole arylation by aryl chlorides were disclosed.[3d] A short ligand optimization was undertaken for the arylation of *N*-methylpyrrole with chlorobenzene (Scheme 3). Dicyclohexylphenyl- and tricyclohexylphosphine afforded moderate conversions to the product, whereas butyldi-1-adamantylphosphine was inefficient. A bowl-shaped triarylphosphine[12] afforded 69% conversion to the monoarylated product. The best results were obtained by employing 2-(dicyclohexylphosphino)biphenyl ligand that was used for subsequent reactions.

The scope of the arylation is shown in Table 2. Excess of *N*-methylpyrrole is used to avoid diarylation. Both electron-rich (entries 5, 9, 11) and electron-poor (entries 2, 4, 6) aryl chlorides are reactive. Introduction of two *N*-methylpyrrole functionalities is possible if *m*-dichlorobenzene is employed (entry 8), and 1,3-bis(1-methyl-1*H*-pyrrol-2-yl)benzene was obtained in 72% yield. 1-Methyl-2-phenylpyrrole is also reactive and can be *para*-tolylated in 63% yield (entry 9). 1-Methylpyrrole-2-carboxylic acid ethyl ester is arylated in moderate yields (entries 10 and 11). 1-Phenylpyrrole can also be arylated (entry 12). Functional groups such as ketone (entry 2) and ester (entry 4) are tolerated. 2-Pyridyl chloride is reactive (entry 13).

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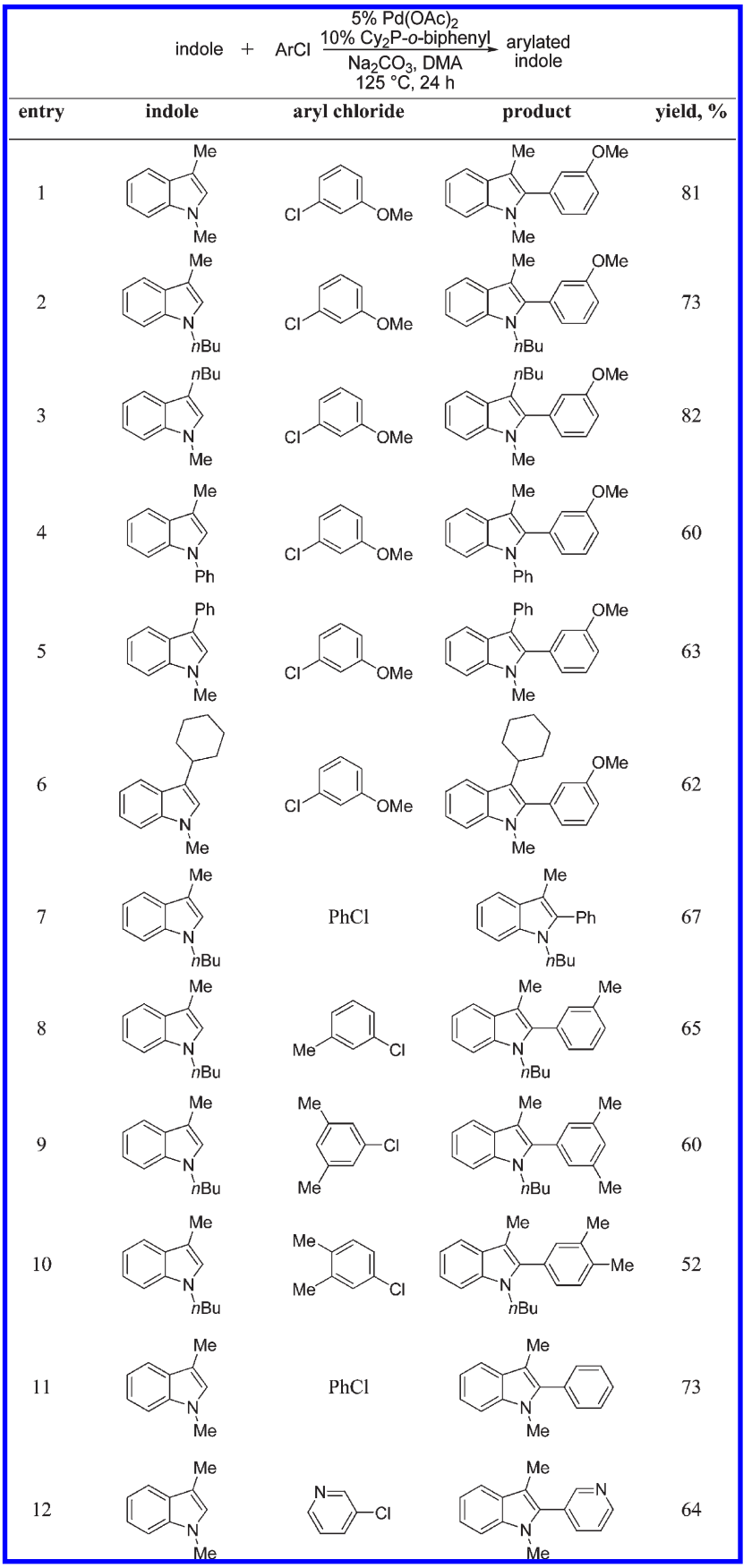
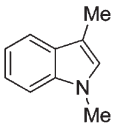
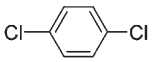
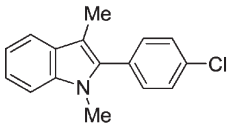
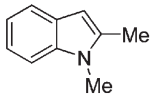
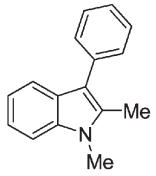
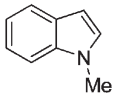
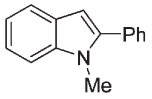
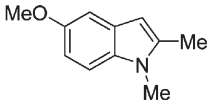
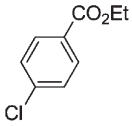
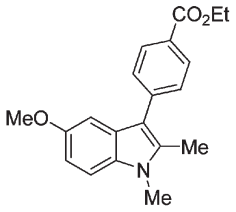
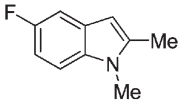
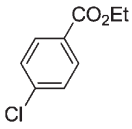
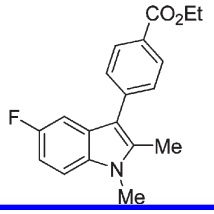
TABLE 1. Indole Arylation by Aryl Chlorides[a]



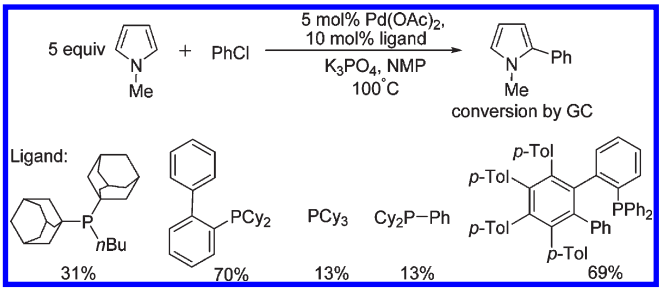
entry	indole	aryl chloride	product	yield, %
1				81
2				73
3				82
4				60
5				63
6				62
7		PhCl		67
8				65
9				60
10				52
11		PhCl		73
12				64

TABLE 1. Continued

entry	indole	aryl chloride	product	yield, %
13				77
14		PhCl		65
15[b]		PhCl		56
16				69
17				92

[a]Conditions: 5 mol % $Pd(OAc)_2$, 10 mol % Cy_2P-*o*-biphenyl, Na_2CO_3 (2 equiv), indole (1 equiv), aryl chloride (5 equiv), DMA solvent, 24 h at 125 °C; isolated yield. [b]Conditions: 5 mol % $Pd(OAc)_2$, 10 mol % $BuAd_2P$, K_3PO_4 (2 equiv), indole (1 equiv), aryl chloride (5 equiv), NMP solvent; 24 h at 125 °C. 1-Methyl-3-phenylindole (7%) and 1-methyl-2,3-diphenylindole (8%) also isolated.

SCHEME 3. Ligand Optimization for Pyrrole Arylation



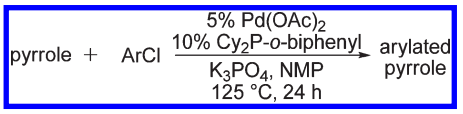
3. Furan Arylation. Many examples of furan arylation by aryl bromides and iodides have been disclosed since the first report by Catellani in 1985.[3b,p,v,4a,4l] However, use of unactivated aryl chlorides in these reactions is rare. We have reported the diarylation of benzofuran by chlorobenzene; unfortunately, the arylation of other furan derivatives was inefficient.[3e] A short ligand optimization revealed once more that 2-(dicyclohexylphosphino)biphenyl affords the best results (Scheme 4). Ligands such as dicyclohexylphenyl-, tricyclohexyl-, and *n*-butyldi-1-adamantylphosphine were not effective. Other Buchwald-type phosphines afford low conversions.

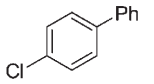
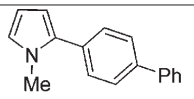
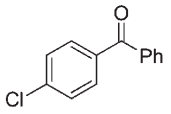
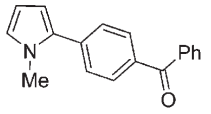
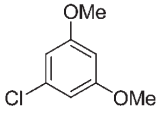
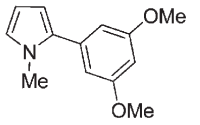
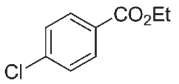
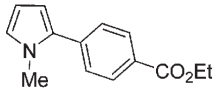
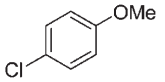
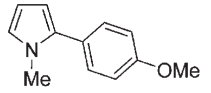
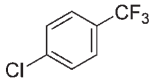
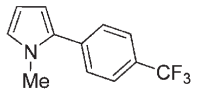
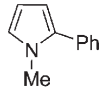
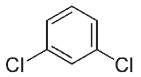
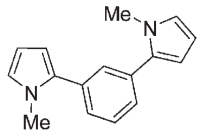
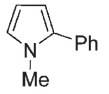
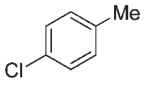
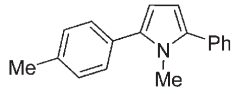
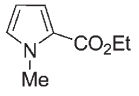
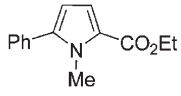
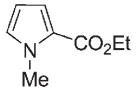
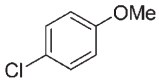
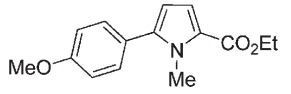
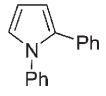
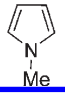
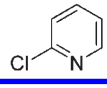
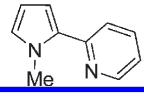
Furan arylation results are presented in Table 3. Furan (entries 1−5, 11), furan-2-carboxylic acid ethyl ester (entries 6, 7), and 2-methylfuran (entries 8−10) can be arylated. Electron-rich (entries 1, 2) as well as electron-poor aryl chlorides (entries 3−6, 8, 9) are reactive. Dichloroarenes can be reacted with furan resulting in substances possessing several heterocyclic moieties (entries 3, 4). 2-Chloropyridine is a competent arylating reagent (entry 11). Yields range from moderate to good. Several equivalents of furan are typically employed to avoid diarylation. For monosubstituted furan arylation, an excess of aryl chloride is used.

Conclusions

We have demonstrated the arylation of indoles, pyrroles, and furans by aryl chlorides. The method employs a palladium acetate catalyst, 2-(dicyclohexylphosphino)biphenyl ligand, and an inorganic base. Electron-rich, electron-poor, and heterocyclic aryl chloride coupling partners can be used, and arylated heterocycles are obtained in moderate to good yields. Unfortunately, it appears that at this point arylation by unactivated aryl chlorides requires extensive optimization of reaction conditions for every substrate class to determine optimal ligand, base, and solvent. *N*-Arylation of indoles

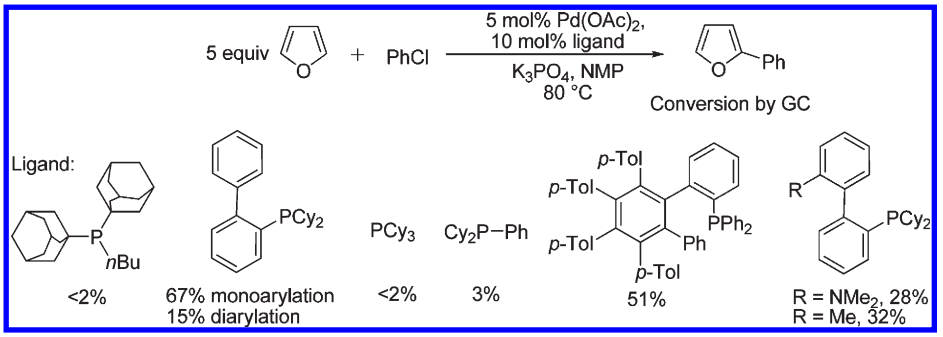
TABLE 2. Pyrrole Arylation[a]



entry	pyrrole	aryl chloride	product	yield, %
1				56
2				51
3				50
4				78
5[b]				70
6				60
7		PhCl		60
8				72
9[c]				63
10[c]		PhCl		53
11[c]				53
12[c]		PhCl		42
13				53

[a]Conditions: 5 mol % $Pd(OAc)_2$, 10 mol % Cy_2P-o-biphenyl, 2 equiv of K_3PO_4, aryl chloride (1 equiv), pyrrole (5 equiv), NMP solvent, 24 h at 125 °C; isolated yield. [b]DMPU solvent. [c]Pyrrole (1 equiv), aryl chloride (3 equiv). Yields are the average of two runs.

SCHEME 4. Ligand Optimization for Furan Arylation



and pyrroles is preferred to C-arylation if unactivated aryl chloride coupling partners are employed. Further investigations are required to solve these problems.

Experimental Section

General Procedure for Coupling of Chloroarenes with 1,3-Disubstituted Indoles and 1,2-Dimethylindole. Outside the glovebox, a 2-dram vial equipped with a magnetic stir bar was charged with $Pd(OAc)_2$ (5 mol %), ligand (10 mol %), base (2 equiv), indole (1 equiv), chloroarene (5 equiv), and anhydrous solvent (4 mL). The vial was flushed with argon, capped, and placed in a preheated oil bath (125 °C) for 24 h. The reaction mixture was allowed to cool to room temperature and quenched with water (40 mL). The resulting suspension was extracted with hexanes (20 mL, then 2 × 10 mL), and combined organic layers were filtered through a pad of Celite. The filtrate was concentrated under vacuum. The crude product was purified by either preparative TLC or flash column chromatography.

2-(3-Methoxyphenyl)-1,3-dimethylindole (Table 1, Entry 1). Palladium acetate (6.0 mg, 0.025 mmol), 2-(dicyclohexylphosphino)biphenyl (17.5 mg, 0.05 mmol), sodium carbonate (106 mg, 1.0 mmol), 1,3-dimethylindole (73 mg, 0.5 mmol), 3-chloroanisole (356 mg, 2.50 mmol), and anhydrous DMA (2 mL). After column chromatography (hexanes/dichloromethane 5/1), 102 mg (81%) of a clear oil was obtained. Product darkens after several hours on the bench. R_f = 0.50 (hexanes/dichloromethane 2/1; visualization by UV). ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 2.30 (s, 3H), 3.63 (s, 3H), 3.86 (s, 3H), 6.93−7.01 (m, 3H), 7.12−7.19 (m, 1H), 7.22−7.29 (m, 1H), 7.31−7.44 (m, 2H), 7.58−7.63 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$, ppm) δ 9.4, 31.0, 55.3, 108.6, 109.2, 113.2, 116.6, 118.8, 119.1, 121.8, 123.1, 128.4, 129.3, 133.5, 137.2, 137.4, 159.4. FT-IR (neat, cm^{-1}) υ 3056, 2914, 1609, 1578, 1469. Anal. Calcd for $C_{17}H_{17}NO$ (251.32 g/mol): C, 81.24; H, 6.82; N, 5.57. Found: C, 80.88; H, 6.90; N, 5.33.

1-Butyl-2-(3-methoxyphenyl)-3-methylindole (Table 1, Entry 2). Palladium acetate (6.0 mg, 0.025 mmol), 2-(dicyclohexylphosphino)biphenyl (17.5 mg, 0.05 mmol), sodium carbonate (106 mg, 1.0 mmol), 1-butyl-3-methylindole (94 mg, 0.5 mmol), 3-chloroanisole (356 mg, 2.50 mmol), and anhydrous DMA (2 mL). After column chromatography (hexanes/dichloromethane 7/1), 108 mg (73%) of a clear oil was obtained. Product darkens after several hours on the bench. R_f = 0.60 (hexanes/dichloromethane 2/1; visualization by UV). ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 0.77 (t, J = 7.4 Hz, 3H), 1.08−1.21 (m, 2H), 1.55−1.65 (m, 2H), 2.24 (s, 3H), 3.85 (s, 3H), 4.00−4.07 (m, 2H), 6.91−7.00 (m, 3H), 7.10−7.16 (m, 1H), 7.19−7.24 (m, 1H), 7.32−7.43 (m, 2H), 7.57−7.61 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$, ppm) δ 9.3, 13.7, 20.1, 32.2, 43.7, 55.3, 108.7, 109.7, 113.3, 116.2, 118.9, 119.0, 121.6, 123.1, 128.6, 129.4, 133.9, 136.3, 137.3, 159.5. FT-IR (neat, cm^{-1}) υ 2958, 2932, 1608, 1578, 1488, 1465. Anal. Calcd for $C_{20}H_{23}NO$ (293.40 g/mol): C, 81.87; H, 7.90; N, 4.77. Found: C, 82.03; H, 8.01; N, 4.73.

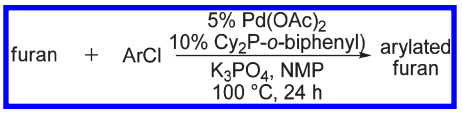
3-Butyl-2-(3-methoxyphenyl)-1-methylindole (Table 1, Entry 3). Palladium acetate (6.0 mg, 0.025 mmol), 2-(dicyclohexylphosphino)biphenyl (17.5 mg, 0.05 mmol), sodium carbonate (106 mg, 1.0 mmol), 3-butyl-1-methylindole (94 mg, 0.5 mmol), 3-chloroanisole (356 mg, 2.50 mmol), and anhydrous DMA (2 mL). After column chromatography (hexanes/dichloromethane 5/1), 121 mg (82%) of a clear oil was obtained. Product darkens after several hours on the bench. R_f = 0.60 (hexanes/dichloromethane 2/1; visualization by UV). ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 0.84 (t, J = 7.2 Hz, 3H), 1.24−1.37 (m, 2H), 1.55−1.66 (m, 2H), 2.66−2.73 (m, 2H), 3.58 (s, 3H), 3.85 (s, 3H), 6.90−7.00 (m, 3H), 7.10−7.17 (m, 1H), 7.21−7.27 (m, 1H), 7.31−7.35 (m, 1H), 7.36−7.43 (m, 1H), 7.62−7.66 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$, ppm) δ 14.0, 22.8, 24.4, 30.8, 33.5, 55.3, 109.3, 113.4, 113.9, 116.2, 119.0, 119.2, 121.6, 123.1, 127.8, 129.3, 133.7, 137.2, 137.5, 159.4. FT-IR (neat, cm^{-1}) υ 2954, 2857, 1609, 1578, 1486, 1468. Anal. Calcd for $C_{20}H_{23}NO$ (293.40 g/mol): C, 81.87; H, 7.90; N, 4.77. Found: C, 81.92; H, 7.95; N, 4.74.

2-(3-Methoxyphenyl)-3-methyl-1-phenylindole (Table 1, Entry 4). Palladium acetate (10.3 mg, 0.046 mmol), 2-(dicyclohexylphosphino)biphenyl (32.2 mg, 0.092 mmol), sodium carbonate (195 mg, 1.84 mmol), 3-methyl-1-phenylindole (190 mg, 0.92 mmol), 3-chloroanisole (656 mg, 4.60 mmol), and anhydrous DMA (3.7 mL). After column chromatography (hexanes/dichloromethane 7/2), 174 mg (60%) of a clear oil was obtained. Product darkens after several hours on the bench. R_f = 0.50 (hexanes/dichloromethane 2/1; visualization by UV). ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 2.43 (s, 3H), 3.64 (s, 3H), 6.70−6.73 (m, 1H), 6.75−6.84 (m, 2H), 7.15−7.39 (m, 9H), 7.64−7.68 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$, ppm) δ 9.6, 55.1, 110.3, 110.7, 113.1, 115.8, 118.9, 120.1, 122.5, 123.1, 126.6, 127.8, 128.9, 129.0, 133.3, 136.7, 137.6, 138.7, 159.0. Signal for one carbon could not be located. FT-IR (neat, cm^{-1}) υ 3059, 1598, 1499, 1460, 1451. Anal. Calcd for $C_{22}H_{19}NO$ (313.39 g/mol): C, 84.31; H, 6.11; N, 4.47. Found: C, 84.28; H, 6.09; N, 4.34.

2-(3-Methoxyphenyl)-1-methyl-3-phenylindole (Table 1, Entry 5). Palladium acetate (9.3 mg, 0.042 mmol), 2-(dicyclohexylphosphino)biphenyl (29.1 mg, 0.083 mmol), sodium carbonate (176 mg, 1.66 mmol), 1-methyl-3-phenylindole (172 mg, 0.83 mmol), 3-chloroanisole (596 mg, 4.10 mmol), and anhydrous DMA (3.3 mL). After column chromatography (hexanes/dichloromethane 3/1), a white solid was obtained. Product was recrystallized from 2,2,4-trimethylpentane to give 165 mg (63%) of white crystals, mp = 95−97 °C. R_f = 0.40 (hexanes/dichloromethane 2/1; visualization by UV). ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 3.70 (s, 3H), 3.72 (s, 3H), 6.84−6.87 (m, 1H), 6.89−6.95 (m, 2H), 7.14−7.22 (m, 2H), 7.25−7.35 (m, 6H), 7.40−7.44 (m, 1H), 7.77−7.82 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$, ppm) δ 31.0, 55.2, 109.6, 113.8, 115.1, 116.6, 119.6, 120.2, 122.2, 123.5, 125.5, 126.9, 128.2, 129.4, 129.8, 133.1, 135.2, 137.3, 137.5, 159.3. FT-IR (neat, cm^{-1}) υ 1600, 1550, 1496, 1468. Anal. Calcd for $C_{22}H_{19}NO$ (313.39 g/mol): C, 84.31; H, 6.11; N, 4.47. Found: C, 84.21; H, 6.11; N, 4.42.

3-Cyclohexyl-2-(3-methoxyphenyl)-1-methylindole (Table 1, Entry 6). Palladium acetate (6.0 mg, 0.025 mmol),

TABLE 3. Furan Arylation[a]



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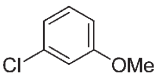
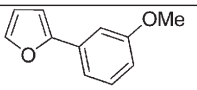
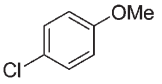
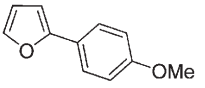
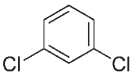
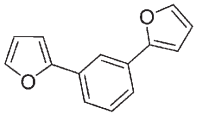
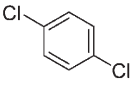
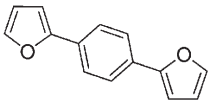
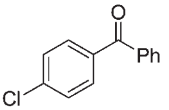
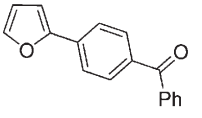
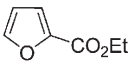
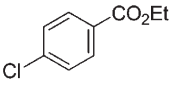
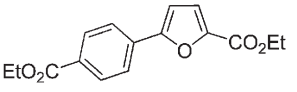
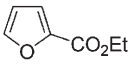
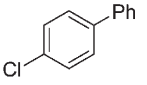
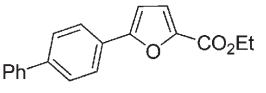
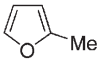
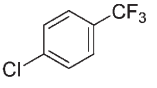
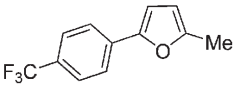
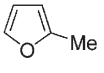
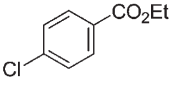
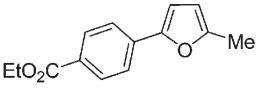
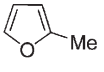
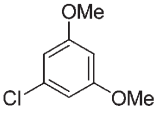
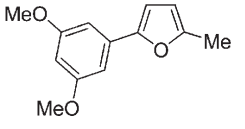
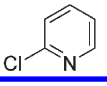
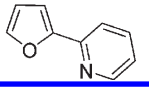
1				92
2				71
3				82
4				74
5				78
6[b]				63
7[b]				54
8				76
9				50
10				54
11				53

[a]Conditions: 5 mol % $Pd(OAc)_2$, 10 mol % Cy_2P-*o*-biphenyl, K_3PO_4 (2 equiv), furan (5 equiv), aryl chloride (1 equiv), NMP solvent, 24 h at 100 °C; isolated yield. [b]Furan (1 equiv), aryl chloride (5 equiv). Yields are the average of two runs.

2-(dicyclohexylphosphino)biphenyl (17.5 mg, 0.05 mmol), sodium carbonate (106 mg, 1.0 mmol), 3-cyclohexyl-1-methylindole (107 mg, 0.50 mmol), 3-chloroanisole (356 mg, 2.50 mmol), and anhydrous DMA (2 mL). After column chromatography (hexanes/dichloromethane 4/1), 99 mg (62%) of a clear oil was obtained. Product darkens after several hours on the bench. R_f = 0.60 (hexanes/dichloromethane 2/1; visualization by UV). ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 1.23−1.34 (m, 3H), 1.69−1.83 (m, 5H), 1.87−2.03 (m, 2H), 2.62−2.75 (m, 1H), 3.53 (s, 3H), 3.86 (s, 3H), 6.87−7.01 (m, 3H), 7.07−7.14 (m, 1H), 7.19−7.23 (m, 1H), 7.30−7.35 (m, 1H), 7.36−7.43 (m, 1H), 7.81−7.86 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$, ppm) δ 26.3, 27.1, 30.7, 33.5, 36.7, 55.3, 109.5, 113.5, 116.4, 118.6, 118.7, 120.7, 121.3, 123.3, 126.3, 129.2, 133.9, 136.6, 137.3, 159.3. FT-IR (neat, cm^{-1}) υ 2926, 2850, 1610, 1578, 1466. Anal. Calcd for $C_{22}H_{25}NO$ (319.44 g/mol): C, 82.72; H, 7.89; N, 4.38. Found: C, 83.19; H, 8.00; N, 4.17.

1-Butyl-3-methyl-2-phenylindole (Table 1, Entry 7). Palladium acetate (6.0 mg, 0.025 mmol), 2-(dicyclohexylphosphino)-biphenyl (17.5 mg, 0.05 mmol), sodium carbonate (106 mg,

1.0 mmol), 1-butyl-3-methylindole (94 mg, 0.5 mmol), chlorobenzene (0.25 mL, 2.50 mmol), and anhydrous DMA (2 mL). After column chromatography (hexanes, then hexanes/diethyl ether 10/1), 89 mg (67%) of a clear oil was obtained. Product darkens after several hours on the bench. R_f = 0.20 (hexanes). ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 0.75 (t, J = 7.4 Hz, 3H), 1.06−1.20 (m, 2H), 1.52−1.63 (m, 2H), 2.24 (s, 3H), 3.98−4.06 (m, 2H), 7.10−7.17 (m, 1H), 7.19−7.26 (m, 1H), 7.33−7.52 (m, 6H), 7.57−7.62 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$, ppm) δ 9.2, 13.6, 20.0, 32.1, 43.6, 108.6, 109.6, 118.8, 118.9, 121.4, 127.7, 128.3, 128.6, 130.6, 132.5, 136.3, 137.4. FT-IR (neat, cm^{-1}) υ 3051, 2957, 2931, 1606, 1464. Anal. Calcd for $C_{19}H_{21}N$ (263.38 g/mol): C, 86.65; H, 8.04; N, 5.32. Found: C, 86.62; H, 7.95; N, 5.11.

1-Butyl-3-methyl-2-*m*-tolylindole (Table 1, Entry 8). Palladium acetate (6.0 mg, 0.025 mmol), 2-(dicyclohexylphosphino)-biphenyl (17.5 mg, 0.05 mmol), sodium carbonate (106 mg, 1.0 mmol), 1-butyl-3-methylindole (94 mg, 0.5 mmol), 3-chlorotoluene (316 mg, 2.50 mmol), and anhydrous DMA (2 mL). After preparative TLC plate was eluted 4 times (hexanes), 90 mg (65%) of a clear oil was obtained. Product darkens after several hours on the bench. R_f = 0.20 (hexanes). ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 0.78 (t, J = 7.3 Hz, 3H), 1.08−1.22 (m, 2H), 1.54−1.66 (m, 2H), 2.25 (s, 3H), 2.44 (s, 3H), 3.99−4.06 (m, 2H), 7.11−7.27 (m, 5H), 7.33−7.41 (m, 2H), 7.58−7.62 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$, ppm) δ 9.3, 13.6, 20.0, 21.5, 32.1, 43.6, 108.5, 109.6, 118.8, 118.9, 121.4, 127.7, 128.2, 128.5, 128.6, 131.2, 132.5, 136.3, 137.6, 137.9. FT-IR (neat, cm^{-1}) υ 2958, 2873, 1608, 1464. Anal. Calcd for $C_{20}H_{23}N$ (277.40 g/mol): C, 86.59; H, 8.36; N, 5.05. Found: C, 86.45; H, 8.37; N, 5.06.

1-Butyl-2-(3,5-dimethylphenyl)-3-methylindole (Table 1, Entry 9). Palladium acetate (6.0 mg, 0.025 mmol), 2-(dicyclohexylphosphino)biphenyl (17.5 mg, 0.05 mmol), sodium carbonate (106 mg, 1.0 mmol), 1-butyl-3-methylindole (94 mg, 0.5 mmol), 5-chloro-*m*-xylene (351 mg, 2.50 mmol), and anhydrous DMA (2 mL). After preparative TLC plate was eluted 4 times (hexanes), 88 mg (60%) of a clear oil was obtained. Product darkens after several hours on the bench. R_f = 0.30 (hexanes). ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 0.79 (t, J = 7.3 Hz, 3H), 1.10−1.24 (m, 2H), 1.55−1.67 (m, 2H), 2.25 (s, 3H), 2.40 (s, 6H), 3.99−4.06 (m, 2H), 7.00 (bs, 2H), 7.06 (bs, 1H), 7.11−7.17 (m, 1H), 7.20−7.26 (m, 1H), 7.33−7.38 (m, 1H), 7.58−7.62 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$, ppm) δ 9.3, 13.6, 20.0, 21.4, 32.1, 43.6, 108.3, 109.6, 118.7, 118.8, 121.2, 128.3, 128.6, 129.4, 132.3, 136.2, 137.7, 137.8. FT-IR (neat, cm^{-1}) υ 2958, 2929, 2872, 1602, 1465. Anal. Calcd for $C_{21}H_{25}N$ (291.43 g/mol): C, 86.55; H, 8.65; N, 4.81. Found: C, 86.32; H, 8.74; N, 4.69.

1-Butyl-2-(3,4-dimethylphenyl)-3-methylindole (Table 1, Entry 10). Palladium acetate (6.0 mg, 0.025 mmol), 2-(dicyclohexylphosphino)-biphenyl (17.5 mg, 0.05 mmol), sodium carbonate (106 mg, 1.0 mmol), 1-butyl-3-methylindole (94 mg, 0.5 mmol), 1-chloro-3,4-dimethylbenzene (351 mg, 2.50 mmol), and anhydrous DMA (2 mL). After preparative TLC plate was eluted 4 times (hexanes), 76 mg (52%) of a clear oil was obtained. Product darkens after several hours on the bench. R_f = 0.20 (hexanes). ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 0.79 (t, J = 7.3 Hz, 3H), 1.09−1.23 (m, 2H), 1.54−1.66 (m, 2H), 2.24 (s, 3H), 2.34 (s, 3H), 2.35 (s, 3H), 3.99−4.06 (m, 2H), 7.09−7.16 (m, 3H), 7.18−7.26 (m, 2H), 7.32−7.37 (m, 1H), 7.58−7.61 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$, ppm) δ 9.3, 13.7, 19.7, 19.9, 20.1, 32.2, 43.6, 108.3, 109.6, 118.7, 118.8, 121.2, 128.1, 128.6, 129.6, 129.9, 131.7, 136.2, 136.5, 137.7. Signal for one carbon could not be located. FT-IR (neat, cm^{-1}) υ 2957, 2931, 2872, 1655, 1610, 1501, 1465.

1,3-Dimethyl-2-phenylindole (Table 1, Entry 11). Palladium acetate (6.0 mg, 0.025 mmol), 2-(dicyclohexylphosphino)-biphenyl (17.5 mg, 0.05 mmol), sodium carbonate (106 mg, 1.0 mmol), 1,3-dimethylindole (73 mg, 0.5 mmol), chlorobenzene (0.25 mL, 2.50 mmol), and anhydrous DMA (2 mL). After column chromatography (hexanes (600 mL), then hexanes/diethyl ether 20/1), an impure product was obtained. After purification by preparative TLC (elution 4 times in hexanes), 81 mg (73%) of a clear oil was obtained. Product darkens after several hours on the bench. This compound is known.[3n] ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 2.29 (s, 3H), 3.62 (s, 3H), 7.12−7.19 (m, 1H), 7.23−7.29 (m, 1H), 7.32−7.36 (m, 1H), 7.38−7.45 (m, 3H), 7.46−7.53 (m, 2H), 7.59−7.63 (m, 1H).

1,3-Dimethyl-2-(pyridin-3-yl)indole (Table 1, Entry 12). Palladium acetate (6.0 mg, 0.025 mmol), 2-(dicyclohexylphosphino)-biphenyl (17.5 mg, 0.05 mmol), sodium carbonate (106 mg, 1.0 mmol), 1,3-dimethylindole (73 mg, 0.5 mmol), 3-chloropyridine (284 mg, 2.50 mmol), and anhydrous DMA (2 mL). After column chromatography (hexanes/ethyl acetate 2/1), 71 mg (64%) of a white solid was obtained, mp = 62−64 °C (2,2,4-trimethylpentane). R_f = 0.50 (hexanes/dichloromethane 2/1; visualization by UV). ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 2.29 (s, 3H), 3.63 (s, 3H), 7.14−7.21 (m, 1H), 7.25−7.32 (m, 1H), 7.33−7.37 (m, 1H), 7.41−7.47 (m, 1H), 7.59−7.64 (m, 1H), 7.70−7.75 (m, 1H), 8.63−8.71 (m, 2H). ^{13}C NMR (75 MHz, $CDCl_3$, ppm) δ 9.3, 31.0, 109.4, 110.1, 119.1, 119.4, 122.4, 123.3, 128.3, 133.9, 137.5, 137.8, 148.9, 151.2. Signal for one carbon could not be located. FT-IR (neat, cm^{-1}) υ 3052, 1571, 1467. Anal. Calcd for $C_{15}H_{14}N_2$ (222.29 g/mol): C, 81.05; H, 6.35; N, 12.60. Found: C, 81.07; H, 6.50; N, 12.57.

2-(4-Chlorophenyl)-1,3-dimethylindole (Table 1, Entry 13). Palladium acetate (6.0 mg, 0.025 mmol), 2-(dicyclohexylphosphino)biphenyl (17.5 mg, 0.05 mmol), sodium carbonate (106 mg, 1.0 mmol), 1,3-dimethylindole (73 mg, 0.5 mmol), 1,4-dichlorobenzene (368 mg, 2.50 mmol), and anhydrous DMA (2 mL). After preparative TLC plate was eluted 4 times (hexanes), 98 mg (77%) of a white solid was obtained, mp = 122−124 °C (2,2,4-trimethylpentane). R_f = 0.20 (hexanes). ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 2.26 (s, 3H), 3.60 (s, 3H), 7.12−7.19 (m, 1H), 7.23−7.29 (m, 1H), 7.30−7.35 (m, 3H), 7.44−7.49 (m, 2H), 7.58−7.62 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$, ppm) δ 9.3, 30.9, 109.0, 109.3, 118.9, 119.3, 122.0, 128.3, 128.7, 130.6, 131.8, 133.8, 136.3, 137.3. FT-IR (neat, cm^{-1}) υ 1491, 1469. Anal. Calcd for $C_{16}H_{14}ClN$ (255.74 g/mol): C, 75.14; H, 5.52; N, 5.48. Found: C, 75.18; H, 5.54; N, 5.43.

1,2-Dimethyl-3-phenylindole (Table 1, Entry 14). Palladium acetate (11 mg, 0.05 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.1 mmol), sodium carbonate (212 mg, 2.0 mmol), 1,2-dimethylindole (145 mg, 1.0 mmol), chlorobenzene (0.5 mL, 5.0 mmol), and anhydrous DMA (4 mL). After preparative TLC plate was eluted 4 times (hexanes), 144 mg (65%) of a white solid was obtained. Product darkens after several hours on the bench. This compound is known.[14a] ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 2.50 (s, 3H), 3.75 (s, 3H), 7.08−7.15 (m, 1H), 7.19−7.26 (m, 1H), 7.27−7.36 (m, 2H), 7.44−7.53 (m, 4H), 7.65−7.70 (m, 1H).

1-Methyl-2-phenylindole, 1-Methyl-3-phenylindole, and 1-Methyl-2,3-diphenylindole (Table 1, Entry 15). Palladium acetate (11 mg, 0.05 mmol), butyldi-1-adamantylphosphine (38 mg, 0.1 mmol), potassium phosphate (425 mg, 2.0 mmol), 1-methylindole (131 mg, 1.0 mmol), chlorobenzene (0.5 mL, 5.0 mmol), and anhydrous NMP (4 mL). After preparative TLC plate was eluted 5 times (hexanes), 116 mg (56%) of 1-methyl-2-phenylindole was obtained as a yellow solid. Also, 36 mg of the 2:3 mixture of 1-methyl-3-phenylindole and 1-methyl-2,3-diphenylindole was obtained as a clear oil. Calculations based on the ratios from NMR spectrum showed that 14.4 mg (7%) of 1-methyl-3-phenylindole and 21.6 mg of 1-methyl-2,3-diphenylindole (8%) were present in the mixture. Products darken after several hours on the bench. These compounds are known.[3h,14b,14c] 1-Methyl-2-phenylindole: ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 3.75 (s, 3H), 6.56 (s, 1H), 7.11−7.17 (m, 1H), 7.22−7.28 (m, 1H), 7.35−7.54 (m, 6H), 7.62−7.66 (m, 1H). A mixture of

1-methyl-3-phenylindole and 1-methyl-2,3-diphenylindole: ^{1}H NMR (300 MHz, $CDCl_3$, ppm) δ 3.69 (s, 3H), 3.85 (s, 3H), 7.14−7.48 (m), 7.64−7.69 (m), 7.78−7.83 (m), 7.93−7.98 (m).

Ethyl 4-(5-Fluoro-1,2-dimethyl-1*H*-indol-3-yl)benzoate (Table 1, Entry 17). Palladium acetate (6 mg, 0.025 mmol), 2-(dicyclohexylphosphino)biphenyl (17 mg, 0.05 mmol), sodium carbonate (106 mg, 1.0 mmol), 5-fluoro-1,2-dimethyl-1*H*-indole (88.7 mg, 0.5 mmol), ethyl 4-iodobenzoate (0.46 g, 2.5 mmol), and anhydrous DMA (2 mL). After column chromatography (hexanes/diethyl ether 80/20), 155 mg (92%) of white crystals were obtained, mp = 149−150 °C (hexanes), R_f = 0.21 (hexanes/diethyl ether 80/20). ^{1}H NMR (500 MHz, $CDCl_3$, ppm) δ 8.13 (d, J = 8.2 Hz, 2H), 7.51 (d, J = 8.2 Hz, 2H), 7.32−7.30 (m, 1H), 7.23−7.21 (m, 1H), 6.98−6.94 (m, 1H), 4.40 (q, J = 6.9, 2H), 3.72 (s, 3H), 2.49 (s, 3H), 1.42 (t, J = 6.9 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) 166.8, 158.5 (d, J_{C-F} = 233.9 Hz), 140.4, 135.9, 133.4, 130.0, 129.1, 127.8, 127.0 (d, J_{C-F} = 10.3 Hz), 113.5, 109.6 (d, J_{C-F} = 20.3 Hz), 109.5 (d, J_{C-F} = 15.5 Hz), 103.7 (d, J_{C-F} = 24.0 Hz), 61.0, 30.1, 14.5, 11.5. FT-IR (neat, cm^{-1}) υ 1705, 1606, 1482, 1272, 1175, 1145, 1127, 1104, 973. Anal. Calcd for $C_{17}H_{17}NO$ (251.32 g/mol): C, 73.29; H, 5.83; N, 4.50. Found: C, 73.46; H, 5.80; N, 4.48.

Ethyl 4-(5-Methoxy-1,2-dimethyl-1*H*-indol-3-yl)benzoate (Table 1, Entry 16). Palladium acetate (6 mg, 0.025 mmol), 2-(dicyclohexylphosphino)biphenyl (17 mg, 0.05 mmol), sodium carbonate (106 mg, 1.0 mmol), 5-methoxy-1,2-dimethyl-1*H*-indole (88.4 mg, 0.5 mmol), ethyl 4-iodobenzoate (0.46 g, 2.5 mmol), and anhydrous DMA (2 mL). After column chromatography (hexanes/diethyl ether 80/20), 112 mg (69%) of white crystals were obtained, mp = 103−104 °C (hexanes), R_f = 0.36 (hexanes/diethyl ether 80/20). ^{1}H NMR (500 MHz, $CDCl_3$, ppm) δ 8.17−8.14 (m, 2H), 7.57−7.54 (m, 2H), 7.23 (d, J = 9.0 Hz, 1H), 7.15 (d, J = 2.3 Hz, 1H), 6.88 (dd, J = 9.0, 2.3 Hz, 1H), 4.40 (q, J = 7.3 Hz, 2H), 3.81 (s, 3H), 3.69 (s, 3H), 2.46 (s, 3H), 1.42 (t, J = 7.3 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) δ 166.9, 154.8, 141.1, 134.9, 132.1, 130.0, 129.2, 127.5, 127.0, 113.1, 111.3, 109.8, 100.7, 60.9, 56.1, 29.9, 14.5, 11.4. FT-IR (neat, cm^{-1}) υ 1706, 1488, 1270, 1103, 720. Anal. Calcd for $C_{17}H_{17}NO$ (251.32 g/mol): C, 74.28; H, 6.55; N, 4.33. Found: C, 74.42; H, 6.58; N, 4.37.

General Procedure for Pyrrole Arylation. Outside the glovebox, a 4-dram vial equipped with a magnetic stir bar was charged with pyrrole and chloroarene. The vial was flushed with argon, capped, and placed inside a glovebox. To this mixture were added 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (2.0 mmol, 425 mg), and anhydrous *N*-methylpyrrolidone (2 mL). The mixture was shaken, and $Pd(OAc)_2$ (0.05 mmol, 11 mg, 5 mol %) was added. The sealed vial was taken out of the glovebox, stirred at room temperature for 15 min, placed in a heating block (125 °C), and stirred vigorously for 24 h. The reaction mixture was allowed to cool to room temperature and then diluted with ethyl acetate (50 mL). The resulting suspension was filtered. The filtrate was concentrated under vacuum to a volume of about 2 mL. The mixture was absorbed on silica gel and subjected to column chromatography. After concentration of the fractions containing the product, the residue was dried under reduced pressure (40 °C) to yield a pure arylated pyrrole. The yields listed in the table are the average of two runs.

2-(Biphenyl-4-yl)-1-methyl-1*H*-pyrrole (Table 2, Entry 1). Palladium acetate (11.4 mg, 0.05 mmol), 1-methyl-1*H*-pyrrole (5.0 mmol, 0.40 g, 0.44 mL), 4-chlorobiphenyl (192 mg, 1.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). After column chromatography (hexanes/ethyl acetate 95/5), pure fractions were combined and solvent was evaporated leaving white crystals. The impure fractions were combined, concentrated and subjected to another column chromatography step (hexanes/ethyl acetate 95/5). The pure fractions were combined and the solvent was evaporated. A total of 136 mg (57% yield) of white crystalline product was obtained. A second experiment under the same conditions gave 54% yield. The compound is known.[14d] R_f = 0.51 (hexanes/ethyl acetate 95/5). ^{1}H NMR (500 MHz, C_6D_6, ppm) δ 7.52−7.45 (m, 4H), 7.34−7.32 (m, 2H), 7.25−7.22 (m, 1H), 7.15−7.14 (m, 2H), 6.49−6.46 (m, 2H), 6.38 (dd, J = 6.3 Hz, 3.5 Hz, 1H), 2.94 (s, 3H).

(4-(1-Methyl-1*H*-pyrrol-2-yl)phenyl)(phenyl)methanone (Table 2, Entry 2). Palladium acetate (11.4 mg, 0.05 mmol), 1-methyl-1*H*-pyrrole (5.0 mmol, 0.40 g, 0.44 mL), (4-chlorophenyl)(phenyl)-methanone (192 mg, 1.0 mmol), 2-(dicyclohexylphosphino)- biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). After column chromatography (hexanes/ethyl acetate 95/5), fractions containing the desired compound were combined and the solvent was evaporated affording 186 mg of crude product. The crude compound was recrystallized from hexanes giving 96 mg (55%) of a yellowish powder. A second experiment under the same conditions gave 47% yield. R_f = 0.15 (hexanes/ethyl acetate 95/5), mp = 75−76 °C (hexanes). ^{1}H NMR (500 MHz, C_6D_6, ppm) δ 7.79−7.76 (m, 4H), 7.20−7.18 (m, 2H), 7.14−7.13 (m, 1H), 7.09−7.06 (m, 2H), 6.45−6.44 (m, 1H), 6.41−6.39 (m, 1H), 6.32−6.31 (m, 1H), 2.94 (s, 3H). ^{13}C NMR (125 MHz, C_6D_6, ppm) δ 195.2, 138.5, 137.7, 135.8, 133.6, 132.0, 130.7, 130.2, 128.4, 128.3, 125.3, 110.8, 108.9, 34.7. FT-IR (neat, cm^{-1}) υ 1653, 1602, 1475, 1446, 1319, 1310,1277, 1186, 1059. Anal. Calcd for $C_{18}H_{15}NO$ (261.32 g/mol): C, 82.73; H, 5.79; N, 5.36. Found: C, 82.60; H, 5.88.

2-(3,5-Dimethoxyphenyl)-1-methyl-1*H*-pyrrole (Table 2, Entry 3). Palladium acetate (11.4 mg, 0.05 mmol), 1-methyl-1*H*-pyrrole (5.0 mmol, 0.40 g, 0.44 mL), 1-chloro-3,5-dimethoxybenzene (185 mg, 1.0 mmol), 2-(dicyclohexylphosphino)-biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). After column chromatography (hexanes/ethyl acetate 90/10), fractions containing the desired compound were combined and the solvent was evaporated. The crude compound was subjected to preparative TLC (2 plates, hexanes/ethyl acetate 90/10, R_f = 0.30) giving 120 mg (52% yield) of a viscous yellow oil. A second experiment under the same conditions gave 48% yield. ^{1}H NMR (400 MHz, C_6D_6, ppm) δ 6.64 (d, J = 2.3 Hz, 2H), 6.54−6.52 (m, 1H), 6.49−6.47 (m, 1H), 6.45−6.43 (m, 1H), 6.34−6.32 (m, 1H), 1.66 (s, 6H), 1.54 (s, 3H). ^{13}C NMR (125 Mz, C_6D_6, ppm) 161.3, 136.0, 134.7, 123.8, 109.4, 108.3, 107.2, 99.5, 54.8, 34.5. FT-IR (neat, cm^{-1}) υ 1592, 1465, 1421, 1279, 1204, 1154, 1065. Anal. Calcd for $C_{13}H_{15}NO_2$: C, 71.87; H, 6.96; N, 6.45. Found: C, 71.89; H, 6.79; N, 6.48.

Ethyl 4-(1-Methyl-1*H*-pyrrol-2-yl)benzoate (Table 2, Entry 4). Palladium acetate (11.4 mg, 0.05 mmol), 1-methyl-1*H*-pyrrole (5.0 mmol, 0.40 g, 0.44 mL), ethyl-4-chlorobenzoate (188 mg, 1.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). The reaction mixture was directly adsorbed onto the silica column. After two successive column chromatographies (both hexanes/ethyl acetate 95/5 eluent) 180 mg (78% yield) of a white powder was obtained. A second experiment under the same conditions gave 78% yield. R_f = 0.19 (hexanes/ethyl acetate 95/5). This compound is known.[14e] ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.08−8.06 (m, 2H), 7.49−7.46 (m, 2H), 6.77−6.76 (m, 1H), 6.34−6.33 (m, 1H), 6.22−6.23 (m, 1H), 4. 39 (q, J = 7.4 Hz, 2H), 3.71 (s, 3H), 1.41 (t, J = 7.4 Hz, 3H).

2-(4-Methoxyphenyl)-1-methyl-1*H*-pyrrole (Table 2, Entry 5). Palladium acetate (11.4 mg, 0.05 mmol), 1-methyl-1*H*-pyrrole (5.0 mmol, 0.40 g, 0.44 mL), 4-chloroanisole (131 mg, 1.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous DMPU (2.0 mL). After column chromatography (hexanes/ethyl acetate 95/5), 131 mg (71% yield) of a white powder was obtained. R_f = 0.38 (hexanes/ethyl acetate 95/5). A second experiment under

the same conditions gave 69% yield. This compound is known.[13] ^{1}H NMR (500 MHz, C_6D_6, ppm) δ 7.22−7.19 (m, 2H), 6.79−6.76 (m, 2H), 6.46 (dd, J = 3.5 Hz, 1.7 Hz, 1H), 6.42−6.41 (m, 1H), 6.40−6.38 (m, 1H), 3.31 (s, 3H), 3.03 (s, 3H).

1-Methyl-2-(4-(trifluoromethyl)phenyl)-1*H*-pyrrole (Table 2, Entry 6). Palladium acetate (11.4 mg, 0.05 mmol), 1-methyl-1*H*-pyrrole (5.0 mmol, 0.40 g, 0.44 mL), 4-chlorobenzotrifluoride (201 mg, 1.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). After column chromatography (hexanes), fractions containing the desired compound were combined and the solvent was evaporated. The crude compound was subjected to another column chromatography (hexanes/ethyl acetate 99/1). The fractions with the product were combined and the solvent was evaporated giving 165 mg (60%) of a viscous yellow oil. A second experiment under the same conditions gave 61% yield. This compound is known.[14f] R_f = 0.23 (hexanes). ^{1}H NMR (400 MHz, C_6D_6, ppm) δ 7.32 (d, J = 8.2 Hz, 2H), 7.04 (d, J = 8.2 Hz, 2H), 6.38−6.36 (m, 1H), 6.33−6.32 (m, 1H), 6.29−6.27 (m, 1H), 2.86 (s, H).

1-Methyl-2-phenyl-1*H*-pyrrole (Table 2, Entry 7). Palladium acetate (11.4 mg, 0.05 mmol), 1-methyl-1*H*-pyrrole (5.0 mmol, 0.40 g, 0.44 mL), chlorobenzene (136 mg, 1.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). After column chromatography (hexanes/ethyl acetate 99/1), 113 mg (62%) of white powder was obtained. A second experiment under the same conditions gave 58% yield. This compound is known.[14f] R_f = 0.28 (hexanes/ethyl acetate 95/5). ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 7.42−7.38 (m, 4H), 7.32−7.25 (m, 1H), 6.73 (dd, J = 4.6, 2.8 Hz, 1H), 6.25−6.23 (m, 1H), 6.22−6.20 (m, 1H), 3.67 (s, 3H).

1,3-Bis(1-methyl-1*H*-pyrrol-2-yl)benzene (Table 2, Entry 8). Palladium acetate (11.4 mg, 0.05 mmol), 1-methyl-2-phenyl-1*H*-pyrrole (1.0 mL, 10.0 mmol), *m*-dichlorobenzene (175 mg, 1.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (850 mg, 2.0 mmol), and anhydrous NMP (3.0 mL). After column chromatography (hexanes/ethyl acetate 96/4), fractions containing the desired compound were combined and the solvent was evaporated. The crude compound was subjected to another column chromatography (hexanes/ethyl acetate 96/4) giving 140 mg (73%) of a yellowish oil. A second experiment under the same conditions gave 70% yield. R_f = 0.16 (hexanes/ethyl acetate 96/4). ^{1}H NMR (500 MHz, $CDCl_3$, ppm) δ 7.52−7.51 (m, 1H), 7.49−7.46 (m, 2H), 7.41−7.39 (m, 1H), 6.80−6.79 (m, 2H), 6.34−6.33 (m, 2H), 6.29−6.28 (m, 2H), 3.76 (s, 6H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) δ 134.5, 133.6, 128.9, 128.5, 127.1, 123.0, 109.0, 108.0 35.3. FT-IR (neat, cm^{-1}) υ 1604, 1490, 1091. Anal. Calcd for $C_{16}H_{16}N_2$ (236.3 g/mol): C, 81.32; H, 6.82; N, 11.85. Found: C, 81.16; H, 6.81; N, 11.69.

1-Methyl-2-phenyl-5-*p*-tolyl-1*H*-pyrrole (Table 2, Entry 9). Palladium acetate (11.4 mg, 0.05 mmol), 1-methyl-2-phenyl-1*H*-pyrrole (1.0 mmol, 141 mg), 4-chlorotoluene (380 mg, 3.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). After column chromatography (hexanes/ethyl acetate 95/5), fractions containing the desired compound were combined and solvent was evaporated. The crude compound was recrystallized (hexanes/ethyl acetate 99/1) giving 140 mg (63%) of white crystals. A second experiment under the same conditions gave 63% yield. R_f = 0.27 (hexanes/ethyl acetate 95/5), mp = 154−155 °C. ^{1}H NMR (500 MHz, C_6D_6, ppm) δ 7.40−7.37 (m, 2H), 7.32−7.30 (m, 2H), 7.23−7.19 (m, 2H), 7.11−7.09 (m, 1H), 7.03 (d, J = 8.2, 2H), 6.51 (s, 2H), 3.15 (s, 3H), 2.16 (s, 3H). ^{13}C NMR (125 MHz, C_6D_6, ppm) δ 137.0, 136.6, 136.1, 134.2, 131.3, 129.1, 128.8, 128.7, 128.4, 126.5, 109.3, 109.0, 33.6, 20.8. FT-IR (neat, cm^{-1}) υ 1548,1490, 1468, 1331. Anal. Calcd for $C_{18}H_{17}N$ (217.26 g/mol): C, 87.41; H, 6.93; N, 5.66. Found: C, 87.25; H, 7.26; N, 5.61.

Ethyl 1-Methyl-5-phenyl-1*H*-pyrrole-2-carboxylate (Table 2, Entry 10). Palladium acetate (11.4 mg, 0.05 mmol), ethyl 1-methyl-1*H*-pyrrole-2-carboxylate (1.0 mmol, 159 mg), chlorobenzene (0.30 mL, 3.0 mmol), 2-(dicyclohexylphosphino)-biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). The reaction mixture was directly adsorbed onto the silica column. After column chromatography (hexanes/ethyl acetate 95/5), 119 mg (51% yield) of a colorless oil was obtained. A second experiment under the same conditions gave 55% yield. This compound is known.[14g] R_f = 0.38 (hexanes/ethyl acetate 95/5). ^{1}H NMR (500 MHz, $CDCl_3$, ppm) δ 7.45−7.38 (m, 5H), 7.04 (d, J = 4.0 Hz, 1H), 6.21 (d, J = 4.0, 1H), 4.30 (q, J = 7.0 Hz, 2H), 3.88 (s, 3H), 1.37 (t, J = 7.0 Hz, 3H).

Ethyl 5-(4-Methoxyphenyl)-1-methyl-1*H*-pyrrole-2-carboxylate (Table 2, Entry 11). Palladium acetate (11.4 mg, 0.05 mmol), ethyl 1-methyl-1*H*-pyrrole-2-carboxylate (1.0 mmol, 160 mg), 1-chloro-4-methoxybenzene (0.37 mL, 3.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). The reaction mixture was directly adsorbed onto the silica column. After column chromatography (hexanes/ethyl acetate 95/5), 145 mg (52%) of a white powder was obtained. A second experiment under the same conditions gave 54% yield. This compound is known.[14h] R_f = 0.14 (hexanes/ethyl acetate 95/5). ^{1}H NMR (500 MHz, $CDCl_3$, ppm) δ 7.31 (d, J = 8.9 Hz, 2H), 7.02 (d, J = 4.0, 1H), 6.96 (d, J = 8.9 Hz, 2H), 6.15 (d, J = 4.0 Hz, 1H), 4.29 (q, J = 6.9 Hz, 2H), 3.85 (s, 6H), 1.36 (t, J = 6.9 Hz, 3H).

1,2-Diphenyl-1*H*-pyrrole (Table 2, Entry 12). Palladium acetate (11.4 mg, 0.05 mmol), 1-phenyl-1*H*-pyrrole (1.0 mmol, 141 mg), chlorobenzene (0.37 mL, 3.0 mmol), 2-(dicyclohexylphosphino)-biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). The reaction mixture was directly adsorbed onto the silica column. After column chromatography (hexanes), 95 mg (44%) of a white powder was obtained. A second experiment under the same conditions gave 40% yield. This compound is known.[14f] R_f = 0.22 (hexanes). ^{1}H NMR (500 MHz, $CDCl_3$, ppm) δ 7.35−7.15 (m, 10H), 6.97 (dd, J = 2.8, 1.8 Hz, 1H), 6.47 (dd, J = 3.4, 1.8 Hz, 1H), 6.39 (dd, J = 3.4, 2.8 Hz, 1H).

2-(1-Methyl-1*H*-pyrrol-2-yl)pyridine (Table 2, Entry 13). Palladium acetate (11.4 mg, 0.05 mmol), 1-methyl-1*H*-pyrrole (5.0 mmol, 0.45 mL), 2-chloropyridine (119.6 mg, 1.0 mmol), 2--(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). The reaction mixture was directly adsorbed onto the silica column. After column chromatography (hexanes/ethyl acetate 95/5), 88 mg (54%) of a colorless oil was obtained. A second experiment under the same conditions gave 51% yield. This compound is known.[14g] R_f = 0.15 (hexanes/ethyl acetate 95/5). ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.56−8.54 (m, 1H), 7.64−7.60 (m, 1H), 7.52−7.50 (m, 1H), 7.07−7.04 (m, 1H),

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6.73−6.72 (m, 1H), 6.57−6.55 (m, 1H), 6.18−6.17 (m, 1H), 3.99 (s, 3H).

General Procedure for Furan Arylation. Outside the glovebox, a 4-dram vial equipped with a magnetic stir bar was charged with furan and chloroarene. The vial was flushed with argon, capped, and placed inside a glovebox. To this mixture were added 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (2.0 mmol, 425 mg), and anhydrous NMP (2 mL). The mixture was shaken, and $Pd(OAc)_2$ (0.05 mmol, 11 mg, 5 mol %) was added. The sealed vial was taken out of the glovebox, stirred at room temperature for 15 min and placed in heating block (100 °C) for 24 h. The reaction mixture was allowed to cool to room temperature and diluted with ethyl acetate (50 mL). Resulting suspension was filtered. The filtrate was concentrated under vacuum to a volume of about 2 mL. The mixture was absorbed on silica gel and subjected to column chromatography. After concentration of the fractions containing the product, the residue was dried under reduced pressure (40 °C) to yield a pure arylated furan. The yields listed in the table are the average of two runs.

2-(3-Methoxyphenyl)furan (Table 3, Entry 1). Palladium acetate (11.4 mg, 0.05 mmol), furan (0.47 mL, 5.0 mmol), 3-chloroanisole (147 mg, 1.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). After column chromatography (hexanes/ethyl acetate 95/5), 167 mg (93% yield) of a light yellow oil was obtained. A second experiment under the same conditions gave 90% yield. This compound is known.[14h] R_f = 0.23 (hexanes/ethyl acetate 95/5). ^{1}H NMR (400 MHz, C_6D_6, ppm) δ 7.39 (s, 1H), 7.31 (d, J = 8.0 Hz, 1H), 7.11−7.07 (m, 2H), 6.70 (d, J = 8.0 Hz, 2H), 6.41 (s, 1H), 6.15−6.13 (m, 1H), 3.31 (s, 3H).

2-(4-Methoxyphenyl)furan (Table 3, Entry 2). Palladium acetate (11.4 mg, 0.05 mmol), furan (0.47 mL, 5.0 mmol), 4-chloroanisole (165 mg, 1.0 mmol), 2-(dicyclohexylphosphino)-biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). After column chromatography (hexanes) 149 mg (73%) of white powder were obtained. A second experiment under the same conditions gave 68% yield. This compound is known.[14h] R_f = 0.24 (hexanes). ^{1}H NMR (500 MHz, C_6D_6, ppm) δ 7.61−7.58 (m, 2H), 7.15−7.13 (m, 1H), 6.77−6.75 (m, 2H), 6,34 (d, J = 4.0 Hz), 6.18−6.16 (m, 1H), 3.25 (s, 3H).

1,3-Di(furan-2-yl)benzene (Table 3, Entry 3). Palladium acetate (11.4 mg, 0.05 mmol), furan (0.94 mL, 10.0 mmol), 1,3-dichlorobenzene (159 mg, 1.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). After column chromatography (hexanes), pure fractions were combined and the solvent was evaporated. The impure fractions were combined, concentrated, and subjected to another column chromatography step (hexanes). The pure fractions were combined and after evaporation of the solvent more product was obtained. A total of 184 mg (80% yield) of a pale yellow oil was obtained. A second experiment under the same conditions gave 83% yield. R_f =0.48 (hexanes). ^{1}H NMR (500 MHz, $CDCl_3$, ppm) δ 7.99−7.98 (m, 1 H), 7.55 (dd, J = 7.4 Hz, 1.7 Hz, 2 H), 7.48 (d, J = 1.7 Hz, 1H), 7.39−7.37 (m, 2H), 6.70 (d, J = 3.4 Hz, 2H), 6.49−6.47 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) δ 153.7, 142.2, 131.3, 129.0, 122.7, 119.1, 111.7, 105.4. FT-IR (neat, cm^{-1}) υ 1614, 1503, 1220, 1156, 1012. Anal. Calcd for $C_{14}H_{10}O_2$ (210.23 g/mol): C, 79.98; H, 4.79. Found: C, 79.80; H, 4.79.

1,4-Di(furan-2-yl)benzene (Table 3, Entry 4). Palladium acetate (11.4 mg, 0.05 mmol), furan (0.47 mL, 5.0 mmol), 1,4-dichlorobenzene (72 mg, 0.5 mmol), 2-(dicyclohexylphosphino)-biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). After column chromatography (hexanes), fractions containing the desired compound were combined and the solvent was evaporated affording white powder (103 mg, 72%). A second experiment under the same conditions gave 76% yield. R_f = 0.28 (hexanes). This compound is known.[14i] ^{1}H NMR (500 MHz, $CDCl_3$, ppm) δ 7.69 (s, 4H), 7.48 (dd, J = 1.8, 0.9 Hz, 2H), 6.67 (dd, J = 3.4, 0.9 Hz, 1H), 6.48 (dd, J = 3.4, 1.8 Hz, 1H).

(4-(Furan-2-yl)phenyl)(phenyl)methanone (Table 3, Entry 5). Palladium acetate (11.4 mg, 0.05 mmol), furan (0.47 mL, 5.0 mmol), (4-chlorophenyl)(phenyl)methanone (238 mg, 1.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). After column chromatography (hexanes), pure fractions were combined and the solvent was evaporated. The impure fractions were combined, solvent was evaporated, and the impure product was recrystallized from hexanes. A total of 205 mg (75% yield) of pale yellow crystalline product was obtained. A second experiment under the same conditions gave 80% yield. R_f = 0.07 (hexanes). This compound is known.[14i] ^{1}H NMR (500 MHz, C_6D_6, ppm) δ 7.77−7.69 (m, 2H), 7.73−7.72 (m, 2H), 7.53−7.51 (m, 2H), 7.14−7.12 (m, 1H), 7.27−7.04 (m, 3H), 6.39−6.37 (m, 1H), 6.12−6.10 (m, 1H).

Ethyl 5-(4-(Ethoxycarbonyl)phenyl)furan-2-carboxylate (Table 3, Entry 6). Palladium acetate (11.4 mg, 0.05 mmol), ethyl 2-furoate (143 mg, 1.0 mmol), ethyl 4-chlorobenzoate (800 mg, 5.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL), reaction temperature 125 °C. The reaction mixture was loaded directly onto the column. After column chromatography (hexanes/ethyl acetate 95/5), fractions containing the desired compound were combined and the solvent was evaporated leaving a white powder (178 mg, 61% yield). A second experiment under the same conditions gave 64% yield. R_f = 0.10 (hexanes/ethyl acetate 95/5), mp 48−49 °C (hexanes). ^{1}H NMR (500 MHz, $CDCl_3$, ppm) δ 8.05 (d, J = 8.6 Hz, 2H), 7.80 (d, J = 8.6 Hz, 2H), 7.22 (d, J = 3.7 Hz, 1H), 6.82 (d, J = 3.7 Hz, 1H), 4.38−4.34 (m, 4H), 1.39−1.36 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$, ppm) 166.0, 158.7, 156.1, 144.7, 133.3 130.4, 130.1, 124.5, 119.8, 108.7, 61.1, 61.2, 14.4, 14.3. FT-IR (neat, cm^{-1}) υ 1718, 1708, 1301, 1265, 1177, 1141, 1100, 1021. Anal. Calcd for $C_{16}H_{16}O_5$ (288.3 g/mol): C, 66.66; H, 5.59. Found: C, 67.14; H, 5.26.

Ethyl 5-(Biphenyl-4-yl)furan-2-carboxylate (Table 3, Entry 7). Palladium acetate (11.4 mg, 0.05 mmol), ethyl 2-furoate (143 mg, 1.0 mmol), 4-chlorobiphenyl (508 mg, 3.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). The reaction mixture was loaded directly onto the column. After column chromatography (hexanes/ethyl acetate 95/5), fractions containing the desired compound were combined and the solvent was evaporated leaving yellowish powder (282 mg). The impure product was recrystallized from hexanes giving 155 mg (52%) of a beige powder. A second experiment under the same conditions gave 55% yield. R_f = 0.13 (hexanes/ethyl acetate 95/5), mp = 95−96 °C (pentane). ^{1}H NMR (500 MHz, C_6D_6, ppm) δ 7.68−7.65 (m, 2H), 7.41−7.37 (m, 4H), 7.22−7.19 (m, 2H), 7.15−7.13−7.11 (m, 2H), 6.26 (d, J = 3.4 Hz, 1H), 4.14 (q, J = 7.5 Hz, 2H), 1.04 (t, J = 7.5 Hz, 3H). ^{13}C NMR (125 MHz, C_6D_6, ppm) δ 158.3, 157.1, 144.5, 141.5, 140.4, 128.8, 128.6, 128.0, 127.5, 127.0, 125.2, 119.6, 106.8, 60.4, 14.1. FT-IR (neat, cm^{-1}) υ 1722, 1479, 1302, 1284, 1271, 1218, 1153, 1022. Anal. Calcd for $C_{19}H_{16}O_3$ (292.33 g/mol): C, 78.06; H, 5.52. Found: C, 78.14; H, 5.54.

2-Methyl-5-(4-(trifluoromethyl)phenyl)furan (Table 3, Entry 8). Palladium acetate (11.4 mg, 0.05 mmol), 2-methylfuran (0.47 mL, 5.0 mmol), 4-chlorobenzotrifluoride (199 mg, 1.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). After column chromatography (hexanes), 189 mg (76%) of a white powder was obtained. A second experiment under the

same conditions gave 76% yield. R_f = 0.62 (hexanes). This compound is known.[14j] ^{1}H NMR (500 MHz, C_6D_6, ppm) δ 7.39−7.32 (m, 4H), 6.31 (d, J = 3.4 Hz, 1H), 5.79 (m, 1H), 1.98 (s, 3H).

Ethyl 4-(5-Methylfuran-2-yl)benzoate (Table 3, Entry 9). Palladium acetate (11.4 mg, 0.05 mmol), 2-methylfuran (0.5 mL, 5.0 mmol), ethyl 4-chlorobenzoate (159 mg, 1.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). After column chromatography (hexanes/ethyl acetate 98/2), fractions containing the desired compound were combined and the solvent was evaporated affording white powder (107 mg, 50% yield). A second experiment under the same conditions gave 50% yield. R_f = 0.14 (hexanes/ethyl acetate 98/2), mp = 52−53 °C. ^{1}H NMR (500 MHz, $CDCl_3$, ppm) δ 8.03−8.01 (m, 2H), 7.67−7.65 (m, 2H), 6.67−6.65 (m, 1H), 6.09−6.08 (m, 1H), 4.37 (q, J = 6.9 Hz, 2H), 2.38 (s, 3 H), 1.40 (t, J = 6.9 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$, ppm) δ 166.5, 153.4, 151.4, 135.1, 130.1, 128.3, 122.9, 108.4, 108.3, 61.0, 14.5, 13.9. FT-IR (neat, cm^{-1}) υ 1699, 1610, 1274, 1178, 1103, 1024. Anal. Calcd for $C_{14}H_{14}O_3$ (230.09 g/mol): C, 73.03; H, 6.13. Found: C, 72.95; H, 6.12.

2-(3,5-Dimethoxyphenyl)-5-methylfuran (Table 3, Entry 10). Palladium acetate (11.4 mg, 0.05 mmol), 2-methylfuran (0.5 mL, 5.0 mmol), 1-chloro-3,5-dimethoxybenzene (172 mg, 1.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous DMPU (2.0 mL). After column chromatography (hexane/ethyl acetate 98/2), fractions containing the desired compound were combined and the solvent was evaporated affording 282 mg (56% yield) of a yellowish oil. A second experiment under the same conditions gave 52% yield. R_f = 0.09 (hexane/ethyl acetate 98/2). ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 6.79 (d, J = 2.3 Hz, 2H), 6.52 (d, J = 3.2 Hz, 1H), 6.35−6.33 (m, 1H), 6.04−6.03 (m, 1H), 3.8 (s, 6H), 2.35 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$, ppm) δ 161.1, 152.1, 133.0, 107.8, 106.6, 101.5, 99.4, 55.5, 31.0, 13.9. FT-IR (neat, cm^{-1}) υ 1592, 1551, 1485, 1426, 1336,1227, 1203, 1155, 1023. Anal. Calcd for $C_{13}H_{14}O_3$ (218.25 g/mol): C, 71.54; H, 6.47. Found: C, 71.79; H, 6.29.

2-(Furan-2-yl)pyridine (Table 3, Entry 11). Palladium acetate (11.4 mg, 0.05 mmol), furan (5.0 mmol, 0.47 mL), 2-chloropyridine (124.7 mg, 1.0 mmol), 2-(dicyclohexylphosphino)biphenyl (35 mg, 0.10 mmol, 10 mol %), K_3PO_4 (425 mg, 2.0 mmol), and anhydrous NMP (2.0 mL). The reaction mixture was directly adsorbed onto the silica column. After column chromatography (pentane/diethyl ether 95/5), 82 mg (52%) of a colorless oil was obtained. A second experiment under the same conditions gave 53% yield. This compound is known.[14k] R_f = 0.15 (pentane/diethyl ether 95/5). ^{1}H NMR (400 MHz, $CDCl_3$, ppm) δ 8.60−8.56 (m, 1H), 7.73−7.67 (m, 2H), 7.54−7.53 (m, 1H), 7.16−7.13 (m, 1H), 7.06−7.05 (m, 1H), 6.54−6.52 (m, 1H).

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Supporting Information Available: Detailed experimental procedures and characterization data for starting materials and reaction optimization tables. This material is available free of charge via the Internet at http://pubs.acs.org.