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Copper-catalyzed Tandem Aerobic Oxidative Cyclization for the Synthesis of Polysubstituted Quinolines via $C(sp^3)/C(sp^2)$-H bonds functionalization

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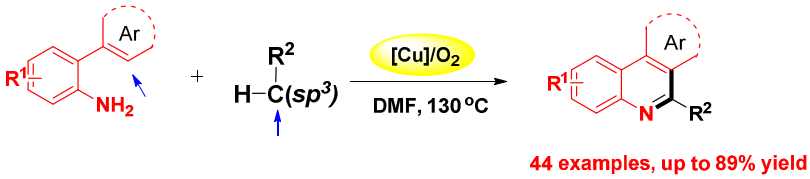


Abstract: One-pot Cu-catalyzed tandem aerobic oxidative cyclization for the synthesis of quinolines from 2-vinylanilines/2-aryl anilines and 2-methylquinolines via $C(sp^3)$-H/$C(sp^2)$-H bonds functionalization has been developed. Dioxygen as an ideal oxidant has been employed for this transformation. The substrates bearing various functional groups are performed well in this process and generate the desired products in moderate to good yields.

Introduction

Transition-metal-catalyzed tandem aerobic oxidative cyclization has been emerged as a powerful tool for the synthesis of heterocyclic

compounds. Among various oxidants, dioxygen as an ideal and potential oxidant has emitted bright light in transition-metal-catalyzed tandem oxidative reaction system. Transition-metal-catalyzed/dioxygen reaction system had been heavily investigated in the past years for its great application prospect in chemical industry.[1] For example, the groups of Glorius,[2] Jiao,[3] and Jiang[4] had reported a series of milestone works about heterocyclic compounds construction through this reaction system. Nevertheless, using transition-metal-catalyzed /dioxygen reaction system for direct and selective C(sp^3)-H bond activation is still challenging due to low reactivity.[5] Thus, the development of novel protocols for the synthesis of heterocyclic compounds through direct C(sp^3)-H bond activation by transition-metal catalyzed/dioxygen reaction system is still highly desirable.

Heterocyclic compounds, as a crucial class of scaffolds, are widely applied in organic synthesis, advanced function materials and pharmaceuticals.[6] In the past several decades, continuous efforts had been devoted to construct polysubstituted heterocyclic compounds.[7] In Particular, quinoline skeletons had been attracted much more attentions due to their privileged scaffold motifs of physicochemical properties, biological activities and pharmacological value,[8] as shown in Figure 1: Compound **A** (18 kDa translocator, TSPO), was a recognized biomarker of neuroinflammation, with high affinity and human genotype insensity.[9]

Compound **B** and **C** were potential and selective PI3Kβ/δ dual inhibitors, as promising target for the treatment of human cancer and a variety of inflammentry diseases.[10] Compound **D** was an antibiotic with antitumor activity, which was isolated from *streptomyoes lavendulae* by Balitz.[11]

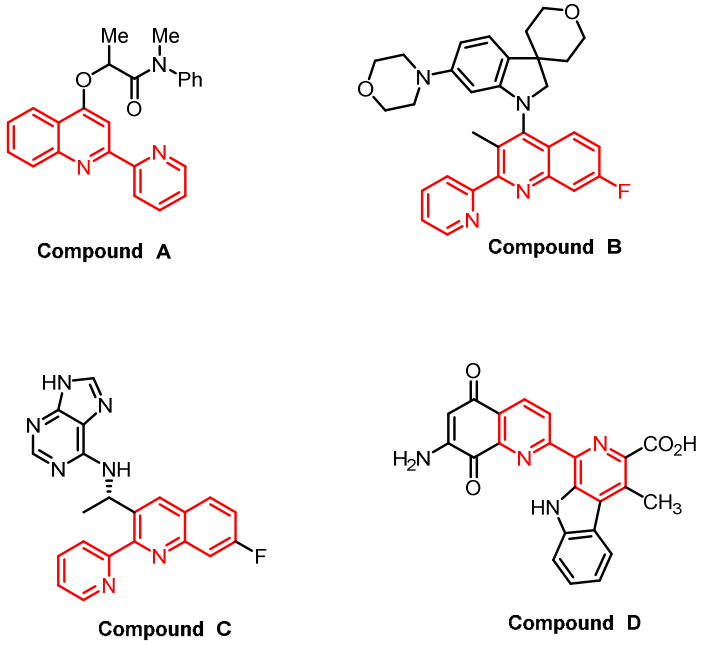
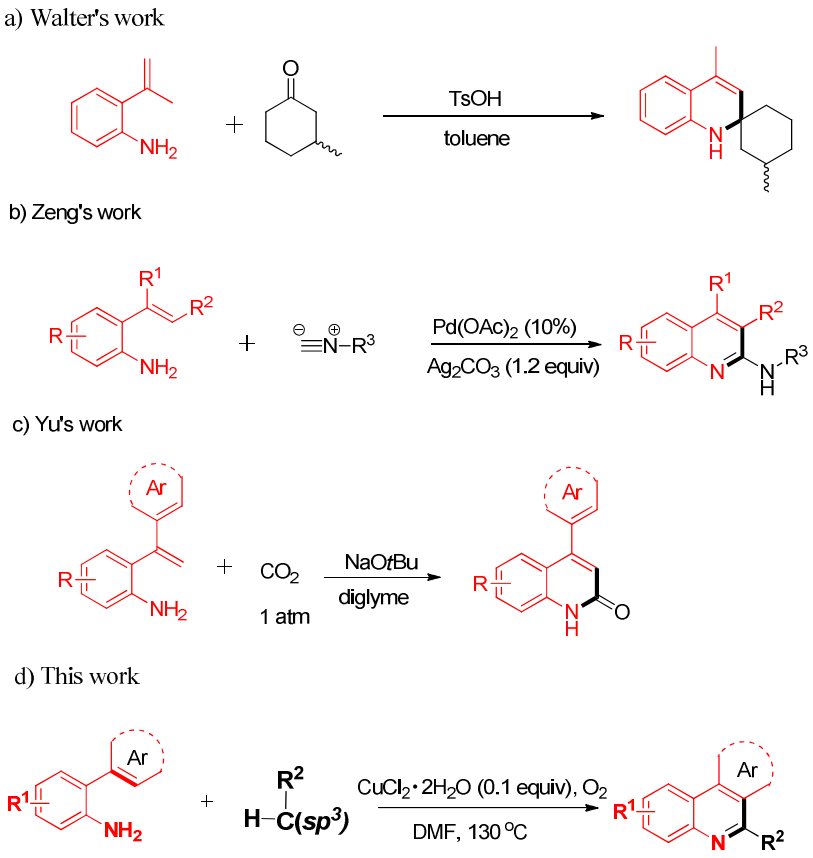


Figure 1. Several Examples of Bioactive Quinoline Derivatives

Therefore, it was not surprising that many different strategies had been developed for the synthesis of quinoline skeletons. Classical methods for the construction of quinolines in organic synthesis had been developed, such as Skraup, Friendlander, Cambes, Niementowski, Pfitzinger, and Povarov reactions.[12] Recently, Walter's group demonstrated that 2-(prop-1-en-2-yl)anilines underwent a facile conversion to synthesize quinolines with 3-methylcyclohexones (Scheme 1, entry a).[13] Zeng's group reported palladium-catalyzed oxidative cyclization to generate 2-aminoquinolines from 2-vinylanilines and isocyanides (Scheme 1, entry

b).[14] Yu's group developed a novel approach to obtain 2-quinolinones with 2-vinylanilines and carbon dioxide (Scheme 1, entry c).[15]

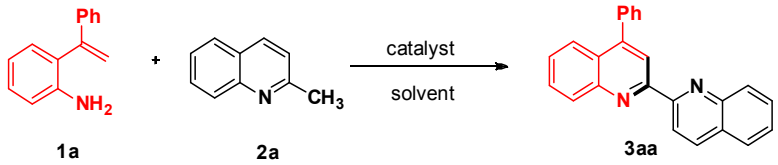


Scheme 1. Synthesis of Substituted Quinoline

Results and Discussion

Inspired by our previous work,[16] herein, we developed one-pot method for the synthesis of substituted quinolines from substituted 2-vinylanilines/2-aryl anilines and 2-methylquinolines with dioxygen as oxidant through Cu-catalyzed cascade oxidative cyclization via C(sp^3)/(sp^2)-H bonds functionalization (Scheme 1, entry d). Initial attempt was started by using 2-(1-phenylvinyl)aniline **1a** and

Table 1. Optimization of Reaction Conditions [a]

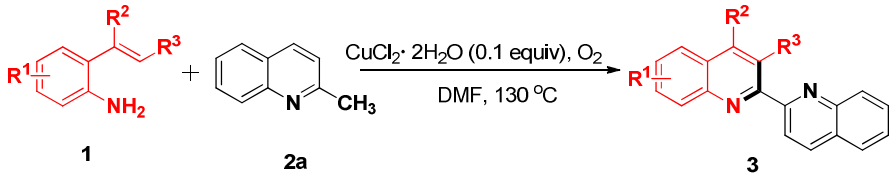


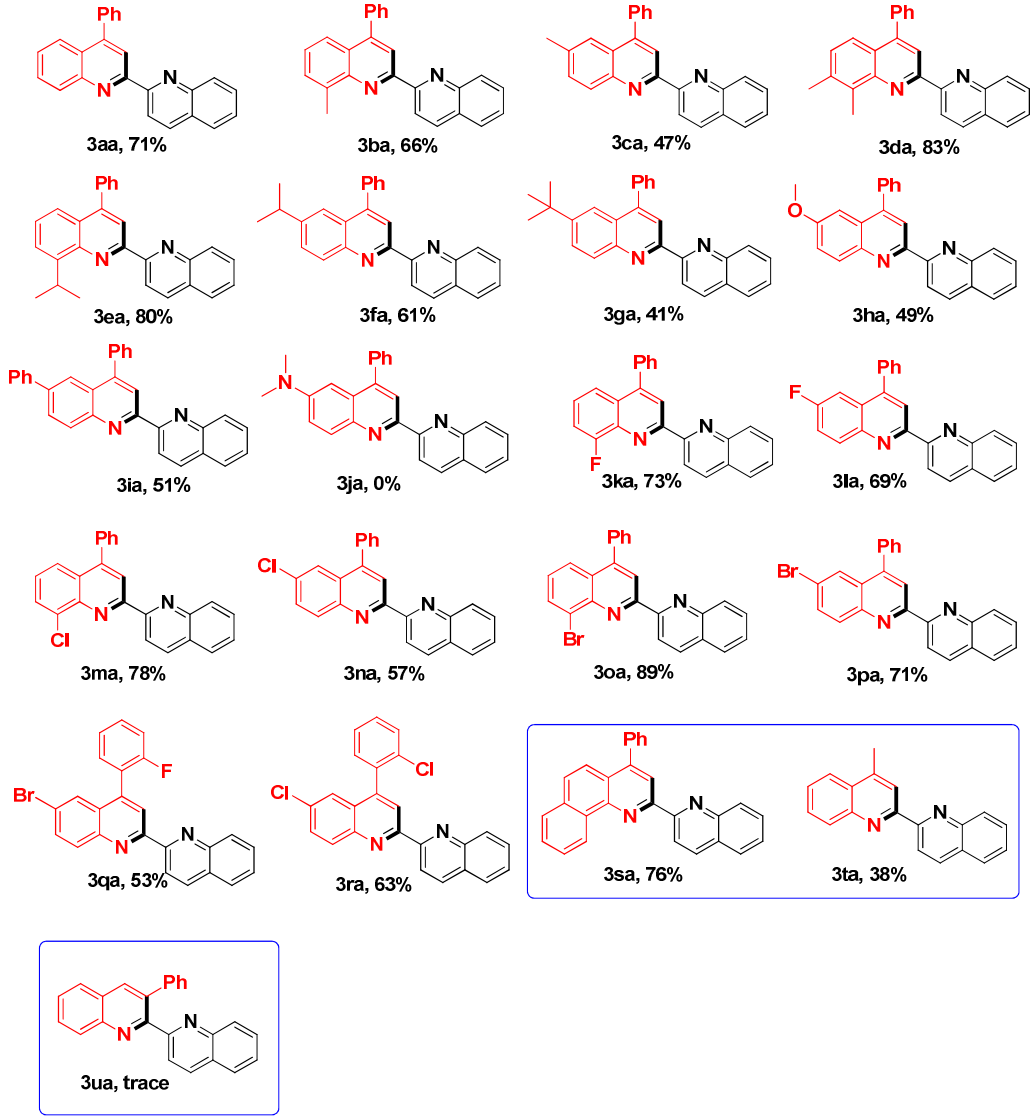
Entry	Catalyst/equiv	Solvent	Yield[b] [%]
1[c]	$CuCl_2·2H_2O$ (0.1)	CH_3NO_2	43
2[c]	$CuCl_2·2H_2O$ (0.1)	DMSO	38
3[c]	$CuCl_2·2H_2O$ (0.1)	DMA	50
4[c]	$CuCl_2·2H_2O$ (0.1)	DMF	70
5	**$CuCl_2·2H_2O$ (0.1)**	**DMF**	**71**
6	$CuCl_2·2H_2O$ (0.1)	NMP	trace
7	$CuCl_2$ (0.1)	DMF	69
8	$CuBr_2$ (0.1)	DMF	54
9	CuI (0.1)	DMF	63
10	CuCl (0.1)	DMF	45
11	CuBr (0.1)	DMF	56
12	$Cu(OAc)_2$ (0.1)	DMF	40
13	$Cu(OTf)_2$ (0.1)	DMF	47
14	$CuCl_2·2H_2O$ (0.05)	DMF	69
15	$CuCl_2·2H_2O$ (0.2)	DMF	62
16	$CuCl_2·2H_2O$ (0.1)	DMF	57
17	$CuCl_2·2H_2O$ (0.1)	DMF	63
18[d]	$CuCl_2·2H_2O$ (0.1)	DMF	59
19[e]	$CuCl_2·2H_2O$ (0.1)	DMF	-
20	-	DMF	-

[a] Reaction conditions: **1a** (0.3 mmol), **2a** (0.6 mmol), catalyst (0.03 mmol), solvent (2 mL), O_2, 130 °C. [b] Isolated yields. [c] TfOH (5 mol%). [d] Under Air. [e] Under N_2.

2-methylquinoline **2a** as model substrates and the desired product 4-phenyl-2,2'-biquinoline **3aa** was formed in 43% yield in the presence of 10 mol% of $CuCl_2·2H_2O$ and 5 mol% TfOH (trifluoromethanesulfonic acid) in CH_3NO_2 at 130 °C under O_2 (Table 1, entry 1). In order to improve the yield, different solvents were screened firstly and the product **3aa** was obtained in 70% yield when DMF was used (Table 1, entry 4).The yield was slightly improved to 71% when the TfOH was removed

Table 2. Scope of Substituted 2-Vinylanilines [a]



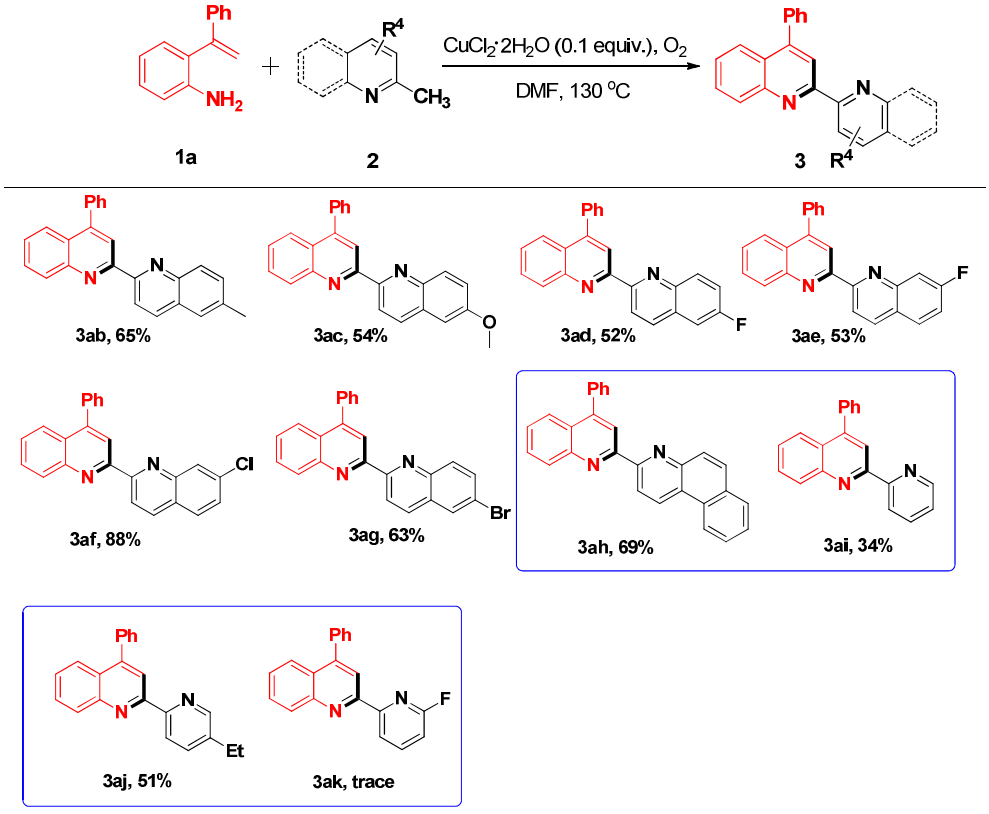


[a] Reaction conditions: **1a** (0.3 mmol), **2a** (0.6 mmol), $CuCl_2 \cdot 2H_2O$ (0.03 mmol), DMF (2 mL), O_2, 130 °C.

(Table 1, entry 5). Then different copper salts were also assessed and $CuCl_2 \cdot 2H_2O$ was proved to be the most efficient catalyst for this reaction (Table 1, entry 7-13). Finally, the dosage of $CuCl_2 \cdot 2H_2O$, temperature and

air were also examined, no better result was obtained (Table 1, entry 14-18). In addition, some control experiments without metal salts and dioxygen were also performed for this reaction and no desired product was detected (Table 1, entry 19-20). Thus the optimized reaction condition was eatablished with $CuCl_2 \cdot 2H_2O$ (0.1 equiv) in DMF at 130°C under O_2.

Table 3. Scope of Substituted 2-Methylquinolines and 2-Methylpyridines [a]

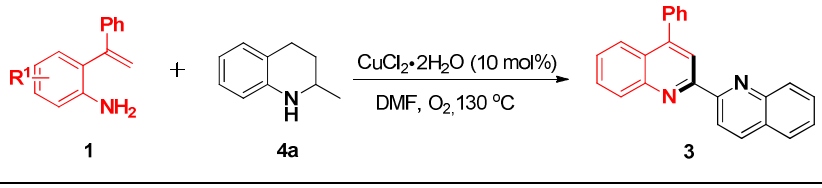


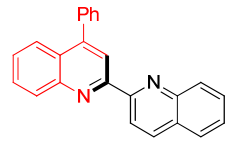
[a] Reaction conditions: **1a** (0.3 mmol), **2** (0.6 mmol), $CuCl_2 \cdot 2H_2O$ (0.03 mmol), DMF (2 mL), O_2, 130 °C.

With the optimized conditions in hand, the scope of 2-vinylanilines/2-aryl anilines and 2-methylquinoline was evaluated and the results are shown in Table 2. Most of substrates transformed well in this reaction system and generated the corresponding quinoline

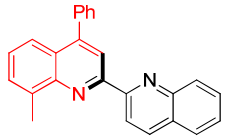
derivatives in moderate to good yields. Obviously, in contrast to substrates with electron-donating groups, electron-withdrawing groups, such as fluorine-, chlorine-, and bromine, on the benzene ring of substrate **1**, produced the target products **3ka-3ra** in good yields. Unfortunately, *N, N*-dimethyl-3-(1-phenylvinyl)benzene-1,4-diamine **1j** was failed to give the desired product **3ja**. Meanwhile, to access the scalability of this protocols, more challenging substrates **1s**, **1t**, and (*E*)-2-styrylaniline **1u** were also employed for this transformation under the optimized conditions, the desired products **3sa** and **3ta** were afforded in 76% and 38% yield respectively, but only trace amount of **3ua** was detected.

Table 4. Scope of Substituted 2-Vinylanilines with 2-Methyl-1,2,3,4-Tetrahydroquinoline [a]

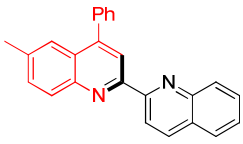




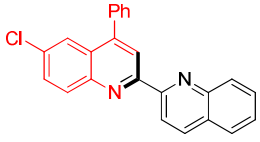
3aa, 33%



3ba, 55%



3ca, 23%

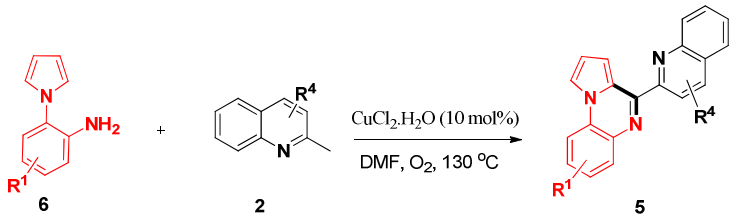


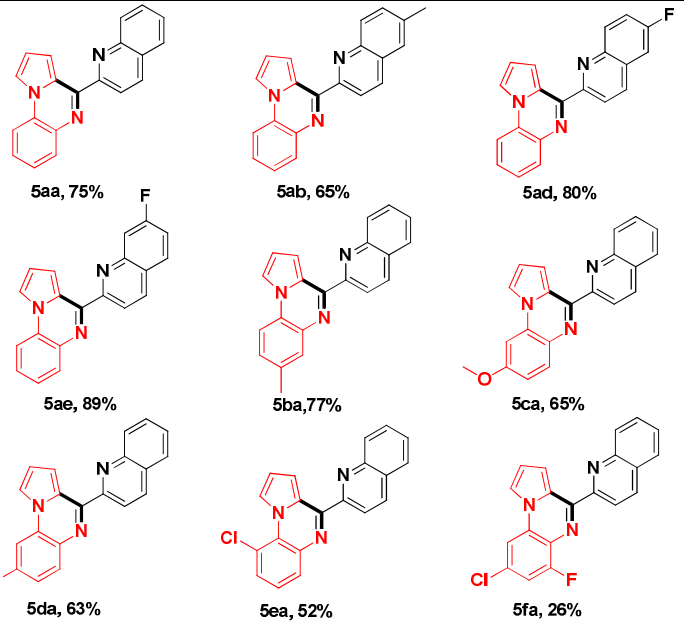
3na, 19%

[a] Reaction conditions: **1a** (0.3 mmol), **4a** (0.6 mmol), $CuCl_2 \cdot 2H_2O$ (0.03 mmol), DMF (2 mL), O_2, 130 °C.

The scope of the substrate investigation was further enlarged to various substituted 2-methylquinolines and 2-methylpyridines. The results are

Table 5. Scope of Substituted 2-Arylanilines with 2-Methylquinolines [a]





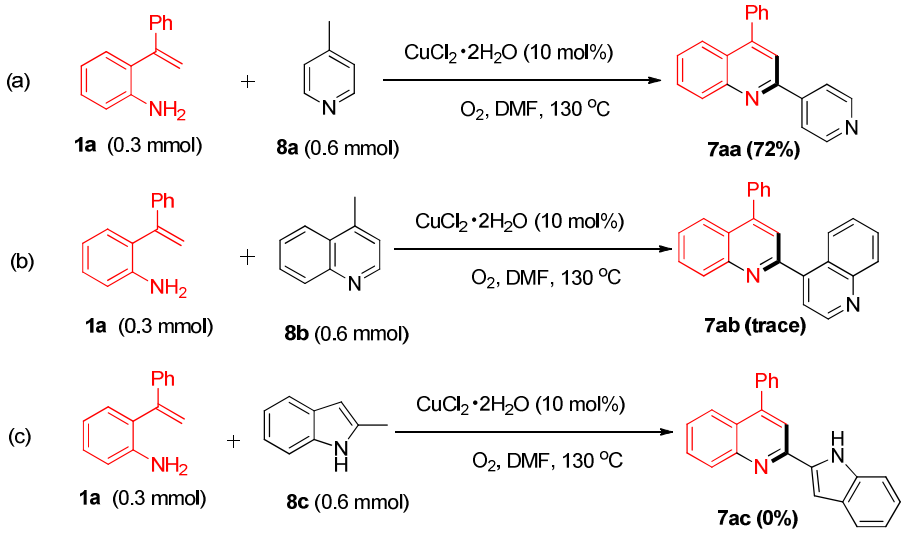
[a] Reaction conditions: **1a** (0.3 mmol), **2** (0.6 mmol), $CuCl_2 \cdot 2H_2O$ (0.03 mmol), DMF (2 mL), O_2, 130 °C.

illustrated in Table 3. 2-Methylquinolines with various substituents at C6, C7 position (**2b-2g**) reacted favourably with substrate **1a** and generated the desired substituted quinolines in moderate yields. Interestingly, 2-methylpyridines **2i** and **2j** were tolerated with this conditions. Whereas 2-fluoro-6-methylpyridine **2k** failed to give the desired product.

We also evaluated the scope of 2-methyl-1,2,3,4-tetrahydroquinoline **4a** with substrate **1** under the optimized conditions (Table 4). The substrate **4a** could also react with substrate **1** and the desired products **3** were isolated in the lower yields. In this process, the substrate **4a** was firstly converted to **2a** under the standard reaction conditions, which was

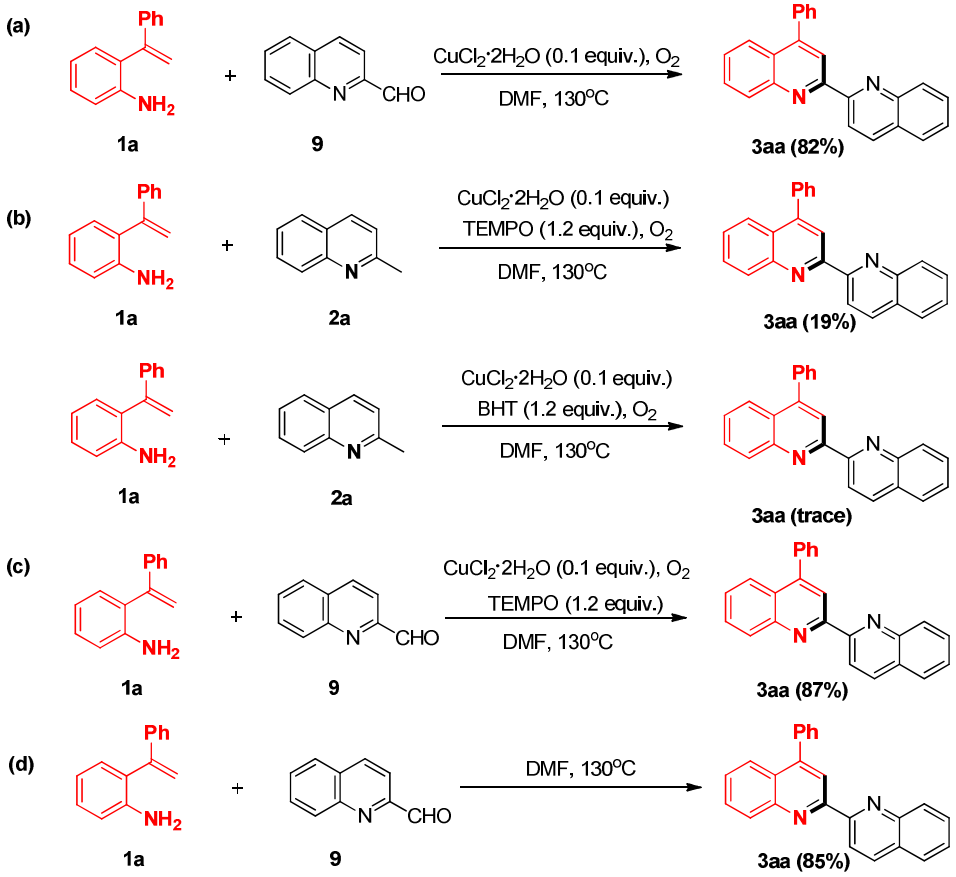
demonstrated by GC-MS (see supporting information, Figure S1).

Based on the success of *ortho*-alkenyl anilines in this reaction and the similar reactivity in many kinds of C(sp^2)-H transformations, we further investigated the reactions of the substrate **6** and **2** and the desired fused heterocyclic compounds **5** were isolated in moderate to good yields under the optimized condtions (Table 5). Above instances demonstrated that this method had emerged as a powerful tool for the synthesis of fused heterocyclic compounds.



Scheme 2. The Scope of 4-Methyl Pyridine, 4-Methyl Quinoline and 2-Methyl Indole

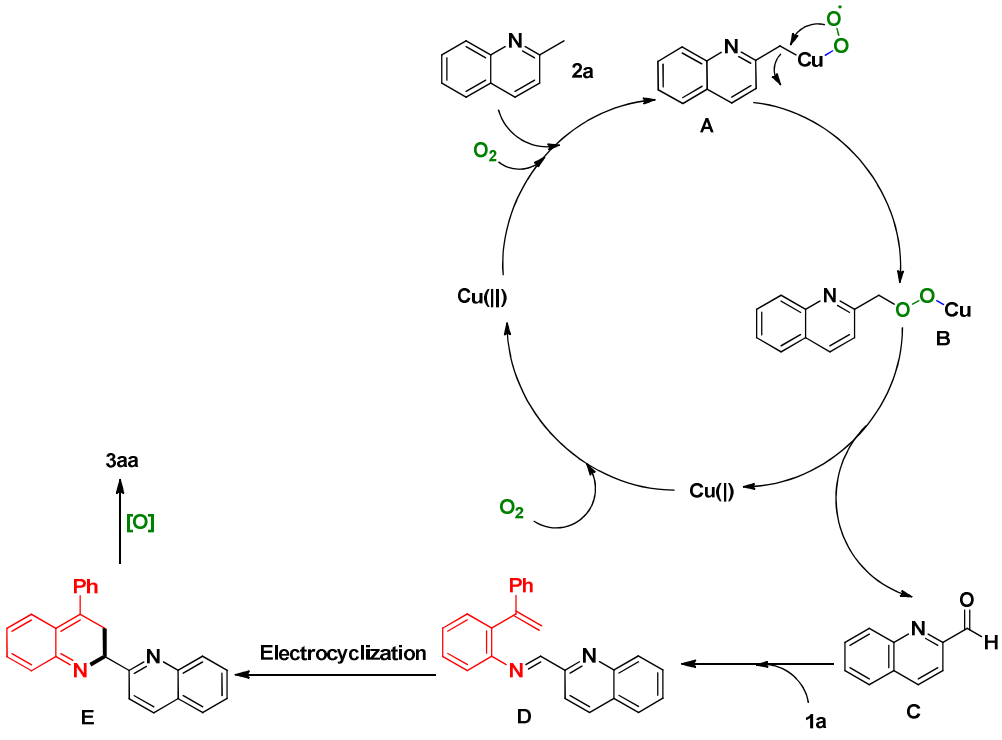
Moreover, the substrates **8a, 8b** and **8c** were also evaluated under the optimized reaction conditions and the results were shown in Scheme 2. Only 3-methylquinoline reacted with **1a** smoothly and generated the desired product **7aa** in 72% yield.



Scheme 3. Control Experiments

To further gather more information about the reaction mechanism, several control experiments were performed. First, the reaction of quinoline-2-carbaldehyde **9** with 2-(1-phenylvinyl)aniline **1a** was carried out under the standard conditions (Scheme 3, entry a) and the product **3aa** was obtained in 82% yield. In addition, further investigation was detected by the GC-MS with 1.0 equiv **1a** and 2.0 equiv **2a** under the standard conditions for 2 h. The molecular ion peak at m/z = 157 corresponding to **9** was found, and the result are illustrated in Figure S2 of supporting information. Above results demonstrated that aldehyde should be the intermediate for this process. Then the radical scavengers of TEMPO

(2,2,6,6,-tetramethylpiperidyl-1-oxyl) and BHT (2,6-di-tert-butyl-4-methylphenol) were added to the reaction mixture respectively, all of the yields were suppressed remarkably (Scheme 3, entry b). These results demonstrated that the reaction should proceed through radical pathway. Furthermore, TEMPO was added into the reaction system of substrate **1a** and quinoline-2-carbaldehyde **9** and the reaction gave the corresponding product **3aa** in 87% yield (Scheme 3, entry c), which indicated the radical reaction should occur in the process of oxidation 2-methylquinoline. When the substrate **1a** and quinoline-2-carbaldehyde **9** was performed in DMF without catalyst and dioxygen at 130 ^{o}C (Scheme 3, entry d), the **3aa** was isolated in 85%



Scheme 4. Proposed Mechanism

yield. This result suggested that the desired product **3aa** was produced via 6π electrocyclization.

Based on these experiments, a plausible mechanism is illustrated in Scheme 4. The 2-methylquinoline **2a** generated to peroxide radical intermediate **A** under the optimized conditions firstly. The radical intermediate **A** was led to the peroxide radical intermediate **B** with dioxygen. Then quinoline-2-carbaldehyde **C,** which was produced from intermediate **B**, reacted with substrate **1a** to generate the imine intermediate **D**. Subsequently, **D** was converted to **E** via 6π electrocyclization process. Finally, the product **3aa** was achieved from intermediate **E** through the oxidation.

Conclusion

In summary, we have developed a direct method for synthesis polysubstituted quinoline derivates with 2-vinylanilines and 2-methylquinolines through C(sp^3/sp^2)-H bonds activation and tandem oxidative cyclization. Additionally, 2-methyl-1,2,3,4-tetrahydroquinoline and 2-aryl anilines also performed well with this reaction system and generated the desired products in moderate yileds. In the presence of copper-catalyst and dioxygen reaction system, various functional groups were tolerated well and gave the corresponding products in moderate to good yields.

Experimental Section

General remarks. ^{1}H NMR and ^{13}C NMR spectra of materials and products were respectively recorded on 300MHz and 75MHz (VARIAN 300M), 400MHz and 100MHz (BRUKER 400M or JNM-ECS 400M) in $CDCl_3$. All chemical shifts are given as δ value (ppm) with reference to tetramethylsilane (TMS) as an internal standard. All compounds were further characterized by HRMS; HRMS was performed on an FT-ICRMS mass instrument and measured with electrospray ionization (ESI). Copies of their ^{1}H NMR and ^{13}C NMR spectra are provided in Supporting Information. Products were purified by flash chromatography on 200–300 mesh silica gels. All melting points were determined without correction. Unless otherwise noted, commercially available reagents and solvents were used without further purification.

General procedure for the synthesis of 2-Vinylanilines and 2-(1H-pyrrol-1-yl)aniline.

1) 1a-1p and 1s were prepared in the method[17]

Aniline (10 mmol), phenylacetylene (1.0 g, 10 mmol) and montraorillonite KSF (1.0 g) are introduced in a round bottomed flask equipped with magnetic stirrer and a reflux condenser. The reaction mixture is heated at 140°C for 5 h and then cooled to room temperature. The products was dissolved with dichloromethane and filtered. Then the solvent were concentrated in vacuo and and the crude was purified by

column chromatography (silica gel, appropriate mixture of petroleum ether /ethyl acetate) to give **1a-1p** and **1s**.

2-(1-phenylvinyl)aniline (1a). Yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.37-7.26 (m, 5 H), 7.19-7.09 (m, 2 H), 6.79-6.75 (m, 1 H), 6.67-6.65 (m, 1 H), 5.778-5.774 (d, *J* = 1.6 Hz, 1 H), 5.338-5.335 (d, *J* = 1.2 Hz, 1 H), 3.51 (br s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ =147.8, 144.6, 140.3, 131.5, 129.4, 129.2, 128.7, 127.9, 127.3, 118.9, 116.7, 116.2.

2-methyl-6-(1-phenylvinyl)aniline (1b). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.35-7.25 (m, 5 H), 7.04 (s, 1 H), 6.98 (s, 1 H), 6.71-6.69 (m, 1 H), 5.79-5.78 (m, 1 H), 5.33-5.32 (m, 1 H), 3.48 (br s, 2 H), 2.13 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ =148.0, 142.7, 140.4, 130.5, 129.2, 129.1, 128.7, 127.6, 127.2, 122.9, 118.4, 116.7, 18.3.

4-methyl-2-(1-phenylvinyl)aniline (1c). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.38-7.26 (m, 5 H), 6.97-6.92 (m, 2 H), 6.60-6.58 (d, *J* = 8.0 Hz, 1 H), 5.765-5.761 (d, *J* = 1.6 Hz, 1 H), 5.326-5.323 (d, *J* = 1.2 Hz, 1 H), 3.31 (br s, 2 H), 2.25 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 148.0, 142.1, 140.4, 131.9, 130.0, 129.2, 128.7, 128.12, 128.08, 127.3, 116.6, 116.4, 21.1.

2,3-dimethyl-6-(1-phenylvinyl)aniline (1d). Yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ = 7.38-7.20 (m, 5 H), 6.90-6.87 (d, *J* = 9.0 Hz, 1 H), 6.66-6.63 (d, *J* = 9.0 Hz, 1 H), 5.79 (d, 1 H), 5.33 (d, 1 H), 3.46 (br

s, 2 H), 2.30 (s, 3 H), 2.06 (s, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$, ppm): δ = 147.6, 141.9, 139.9, 136.4, 128.4, 127.9, 127.6, 126.6, 125.3, 120.7, 119.8, 115.9, 20.6,13.0.

2-isopropyl-6-(1-phenylvinyl)aniline (1e). Yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ = 7.36-7.26 (m, 5 H), 7.17-7.14 (m, 1 H), 6.99-6.96 (m, 1 H), 6.82-6.77 (m, 1 H), 5.83-5.81 (t, *J* = 3.0 Hz, 1 H), 5.35-5.34 (t, *J* = 3.0 Hz, 1 H), 3.52 (br s, 2 H), 2.93-2.79 (m, 1 H), 1.28-1.27 (d, *J* = 3.0 Hz, 3 H), 1.25-1.24 (d, *J* = 3.0 Hz, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$, ppm): δ = 147.6, 140.8, 139.7, 132.6, 128.5, 128.0, 126.5, 124.7, 118.0, 116.1, 27.7, 22.3.

4-isopropyl-2-(1-phenylvinyl)aniline (1f). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.39-7.29 (m, 5 H), 7.04-7.02 (m, 1 H), 6.98-6.97 (d, *J* = 4.0 Hz, 1 H), 6.65-6.63 (d, *J* = 8.0 Hz, 1 H), 5.79 (d, 1 H), 5.35 (d, 1 H), 3.35 (br s, 2 H), 2.87-2.77 (m, 1 H), 1.23-1.21 (d, *J* = 8.0 Hz, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 147.6, 141.8, 139.8, 139.0, 128.9, 128.7, 128.2, 127.4, 126.8, 126.7, 116.1, 115.8, 33.3, 24.4.

4-(tert-butyl)-2-(1-phenylvinyl)aniline (1g). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.37-7.23 (m, 5 H), 7.18-7.12 (m, 2 H), 6.59-6.57 (d, *J* = 8.0 Hz, 1 H), 5.77 (s, 1 H), 5.33 (s, 1 H), 3.37 (br s, 2 H), 1.28 (s, 9 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 147.6, 141.3, 141.0, 139.6, 128.4, 127.9, 127.5, 126.8, 126.6, 125.5, 115.8, 115.2, 33.8, 31.5.

4-methoxy-2-(1-phenylvinyl)aniline (1h). Brown oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.37-7.27 (m, 5 H), 6.77-6.71 (m, 2 H), 6.63-6.61 (d, *J* = 8.0 Hz, 1 H), 5.788-5.785 (d, *J* = 1.2 Hz, 1 H), 5.340-5.337 (d, *J* = 1.2 Hz, 1 H), 3.73 (s, 3 H), 3.23 (br s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 152.4, 147.1, 139.4, 137.6, 128.5, 128.0, 126.6, 116.8, 116.0, 114.6, 55.7.

3-(1-phenylvinyl)-[1, 1'-biphenyl]-4-amine (1i). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.80-7.45 (m, 12 H), 6.93-6.90 (m, 1 H), 6.061-6.058 (d, *J* = 1.2 Hz, 1 H), 5647-5.643 (d, *J* = 1.6 Hz, 1 H), 3.78 (br s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ =147.4, 143.9, 141.2, 139.8, 129.6, 129.0, 128.9, 128.5, 127.7, 127.6, 127.0, 126.61, 126.55, 116.5, 116.3.

2-fluoro-6-(1-phenylvinyl)aniline (1k). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.50-7.41 (m, 5 H), 7.13-7.02 (m, 2 H), 6.83-6.78 (m, 1 H), 5.929-5.926 (d, *J* = 1.2 Hz, 1 H), 5.488-5.485 (d, *J* = 1.2 Hz, 1 H), 3.74 (br s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 152.9-150.6 (*J* = 230.0 Hz), 146.29-146.26 (*J* = 3.0 Hz), 139.4, 132.8-132.7 (*J* = 10.0 Hz), 129.33-129.30 (*J* = 3.0 Hz), 128.8, 128.4, 126.8, 126.1-126.0 (*J* = 10.0 Hz), 117.6-117.5 (*J* = 10.0Hz), 116.6, 114.5-114.3 (*J* = 20.0 Hz).

4-fluoro-2-(1-phenylvinyl)aniline (1l). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.41-7.33 (m, 5 H), 6.94-6.88 (m, 2 H),

6.67-6.64 (m, 1 H), 5.849-5.846 (d, J = 1.2 Hz, 1 H), 5.395-5.392 (d, J = 1.2 Hz, 1 H), 3.47 (br s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 157.3-154.9 (J = 240.0 Hz), 146.4, 140.09-140.07 (J = 2.0 Hz), 139.1, 128.7, 128.3,126.6, 117.2, 117.0, 116.6, 116.5-116.4 (J = 10.0 Hz), 115.3-115.1 (J = 20.0 Hz).

2-chloro-6-(1-phenylvinyl)aniline (1m). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.44-7.32 (m, 6 H), 7.11-7.09 (m, 1 H), 6.79-6.75 (m, 1 H), 5.90 (s, 1 H), 5.43 (s, 1 H), 4.06 (br s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 146.7, 140.8, 139.1, 129.3, 128.9, 128.8, 128.42, 128.37, 126.7, 119.5, 118.2, 116.7.

4-chloro-2-(1-phenylvinyl)aniline (1n). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.32-7.28 (m, 5 H), 7.10-7.07 (m, 2 H), 6.59-6.57 (d, J = 8.0 Hz, 1 H), 5.788-5.785 (d, J = 1.2 Hz, 1 H), 5.334-5.331 (d, J = 1.2 Hz, 1 H), 3.48 (br s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 146.8, 143.3, 139.6, 130.9, 129.3, 129.20, 129.15, 129.0, 127.2, 123.4, 117.4, 117.3.

2-bromo-6-(1-phenylvinyl)aniline (1o). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.44-7.42 (m, 1 H), 7.36-7.32 (m, 5 H), 7.08-7.06 (m, 1 H), 6.68-6.64(m, 1 H), 5.84 (d, 1 H), 5.37 (d, 1 H), 4.05 (br s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 146.8, 141.8, 139.0, 132.1, 130.0, 128.8, 128.5, 128.4, 126.7, 118.8, 116.8, 109.8.

4-bromo-2-(1-phenylvinyl)aniline (1p). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.27-7.21 (m, 5 H), 7.17-7.13 (m, 2 H), 6.47-6.45 (d, *J* = 8.0 Hz, 1 H), 5.705-5.703 (d, *J* = 0.8 Hz, 1 H), 5.252-5.250 (d, *J* = 0.8 Hz, 1 H), 3.45 (br s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 146.7, 143.8, 139.6, 133.7, 132.1, 129.8, 129.4, 129.0, 127.3, 117.8, 117.5, 110.6.

2-(1-phenylvinyl)naphthalen-1-amine (1s). Brown solid. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.87-7.85 (d, *J* = 8.0 Hz, 2 H), 7.52-7.25 (m, 10 H), 6.02-5.98 (d, *J* = 14.0 Hz, 1 H), 5.51-5.48 (d, *J* = 14.0 Hz, 1 H), 4.08 (br s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 147.4, 140.0, 139.1, 134.0, 128.9, 128.6, 128.5, 128.2, 126.9, 125.8, 125.2, 123.7, 121.7, 121.2, 118.3, 116.7.

2) Substrates 1q-1r were prepared in the method[18]

To a solution of methyltriphenylphosphonium bromide (4.64 g, 13 mmol), *t*BuONa (2.50 g, 26 mmol) in THF (100 mL) was added, then the resulting reaction mixture was stirred at room temperature for 5 min. Afterwards (2-aminophenyl)(phenyl)methanone (10 mmol) was added and the reaction solution was stirred at 65 ^{o}C overnight. Then the solvent was removed under reduced pressure and the residue was purified by silica gel flash chromatography (eluent: petroleum ether /ethyl acetate = 20 / 1) to afford the materials **1q-1r**.

4-bromo-2-(1-(2-fluorophenyl)vinyl)aniline (1q). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.29-7.04 (m, 6 H), 6.56-6.54 (d, *J* = 8.0 Hz, 1 H), 5.85 (d, 1 H), 5.59 (d, 1 H), 3.66 (br s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 162.1-159.7 (*J* = 240.0 Hz), 143.4, 141.1, 133.1, 132.0, 130.94, 130.91, 130.3, 124.91-124.88 (*J* = 3.0 Hz), 122.2, 117.8, 117.0-116.7 (*J* = 30.0 Hz), 110.5.

4-chloro-2-(1-(2-chlorophenyl)vinyl)aniline (1r). Orange oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.38-7.25(m, 4 H), 7.04-7.01 (m, 1 H), 6.90-6.89 (d, *J* = 4.0 Hz, 1 H), 6.62-6.59 (d, *J* = 12.0 Hz, 1 H), 5.69 (d, 1 H), 5.62 (d, 1 H), 3.85 (br s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 144.4, 142.3, 140.3, 131.0, 130.2, 129.34, 129.25, 128.4, 128.2, 127.1, 122.8, 121.3, 117.1.

3) 1t were prepared in the method[19]

To a stirred solution of Ph_3PMeBr (1.5 equiv., 12.2 mmol) in Dry THF (15 mL) was added KO^{t}Bu (1.5equiv. 12.2 mmol) in portions under nitrogen. After the mixture was stirred at room temperature for 0.5 h, a solution of corresponding benzophenone (1 equiv. 8.14 mmol) in THF (15 mL) was added dropwise. The reaction mixture was then stirred at room temperature under nitrogen overnight. The reaction mixture was quenched with water and extracted with ethyl acetate (50 mL ×2). The combined organic layers was washed with saturated $NaHCO_3$ (50 mL) and brine (50 mL), dried over anhydrous Na_2SO_4, and concentrated on

rotary evaporator under vacuum and purified by column chromatography (silica gel, appropriate mixture of petroleum ether /ethyl acetate) to afford **1t**.

2-(prop-1-en-2-yl)aniline (1t). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.08-7.03 (m, 2 H), 6.75-6.69 (m, 2 H), 5.29 (d, 1 H), 5.06 (d, 1 H), 3.83 (br s, 2 H), 2.07 (d, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 144.1, 143.4, 129.9, 128.9, 128.5, 118.8, 116.2, 116.0, 24.6.

4) 1u were prepared in the method[20]

The general procedure was followed 2-bromoaniline (2.0 mmol, 1.0 equiv.), trans-2-phenyl-vinylboronic acid (3.0 mmol, 1.5 equiv.), 10 mmol % of $Pd(PPh_3)_4$ (0.2 mmol) and 4 equiv. of K_2CO_3 (8.0 mmol) were added to a mixed solvent of toluene, EtOH and H_2O (5/2/1, 4 mL). The reaction mixtrure was poured into water and extracted with diethyl ether for several times. The combined organic layers were dried over Na_2SO_4. Filtered and concentrated. The residue was purified by column chromatography (petroleum ether /ethyl acetate) to afford the products **1u**.

(E)-2-styrylaniline (1u). white solid. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.56-7.54 (m, 2 H), 7.46-7.44 (m, 1 H), 7.42-7.38 (m, 2 H), 7.32-7.28 (m, 1 H), 7.22-7.18 (d, *J* = 16.0 Hz, 1 H), 7.17-7.13 (m, 1 H), 7.05-7.01 (d, *J* = 16.0 Hz, 1 H), 6.88-6.84 (m, 1 H), 6.75-6.73 (m, 1 H),

3.77 (br s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ =143.8, 137.5, 130.2, 128.62 128.60, 127.5, 127.1, 126.4, 124.1, 123.8, 119.1, 116.2.

5) 4a-4f were prepared in the method[21]

Compound 4a was purchased from commercial sources and used as received. Compounds 4b-4f were prepared in the following method. A screw-cap vial containing a stirring bar, was added 2-iodoanilines (2.0 mmol), CuI (10 mol %), DMEDA (*N,N'*-Dimethyl-1,2-ethanediamine, 20 mol %), K_3PO_4 (2.2 equiv), pyrrole (1.2 equiv), and toluene (2.0 mL). The mixture was stirred at 110 ^{o}C for 24 h under argon. The reaction mixture was diluted with ethyl acetate (50 mL) after cooling to room temperature. The mixture was filtered through a plug of silica gel and additional ethyl acetate was used to elute the silica gel. The filtrate was concentrated and the resulting residue was purified by column chromatography (silica gel, petroleum ether/ethyl acetate) to provide 2-(1H-pyrrol-1-yl)aniline.

5-methyl-2-(1H-pyrrol-1-yl)aniline (4b). White solid. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.03-7.01 (d, *J* = 8.0 Hz, 1 H), 6.80-6.79 (m, 2 H), 6.60-6.56 (m, 2 H), 6.32-6.31 (m, 2 H), 3.62 (br, 2 H), 2.30 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 141.9, 138.6, 127.0, 125.2, 121.9, 119.2, 116.6, 109.2, 21.2.

4-methoxy-2-(1H-pyrrol-1-yl)aniline (4c). White solid. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 6.85-6.84 (m, 2 H), 6.79-6.73 (m, 3 H),

6.34-6.33 (m, 2 H), 3.74 (s, 3 H), 3.44 (br, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 152.5, 135.5, 128.1, 121.7, 117.3, 114.8, 112.5, 109.5, 55.9.

4-fluoro-2-(1H-pyrrol-1-yl)aniline (4d). White solid. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 6.91-6.87 (m, 2 H), 6.83-6.82 (d, *J* = 2.0 Hz, 2 H), 6.74-6.70 (m, 1 H), 6.35-6.34 (m, 2 H), 3.59 (br, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 156.7-154.3 (d, *J* = 236.3 Hz, 1 C), 138.1-138.1(d, *J* = 2.4 Hz, 1 C), 127.7-127.6 (d, *J* = 9.5 Hz, 1 C), 121.5, 116.7-116.7 (d, *J* = 8.2 Hz, 1 C), 115.3-115.0 (d, *J* = 21.9 Hz, 1 C), 114.1-113.8 (d, *J* = 23.6 Hz, 1 C), 109.8.

5-chloro-2-(1H-pyrrol-1-yl)aniline (4e). White solid. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.06-7.04 (d, *J* = 8.4 Hz, 1 H), 6.79-7.77 (m, 3 H), 6.75-6.72 (m, 1 H), 6.34-6.33 (m, 2 H), 3.77 (br, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 143.2, 134.0, 128.2, 125.9, 121.6, 118.2, 115.6, 109.8.

4-chloro-2-fluoro-6-(1H-pyrrol-1-yl)aniline (4f). White solid. ^{1}H NMR (400 MHz, $CDCl_3$, ppm): δ = 7.05-7.02 (m, 1 H), 6.99-6.98 (m, 1 H), 6.83-6.82 (m, 2 H), 6.36-6.35 (m, 2 H), 3.80 (br, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$, ppm): δ = 152.5-150.1 (d, *J* = 241.2 Hz, 1 C), 130.0-129.8 (d, *J* = 13.9 Hz, 1 C), 129.0-128.9 (d, *J* = 6.2 Hz, 1 C), 124.5, 122.4-122.4 (d, *J* = 3.3 Hz, 1 C), 121.3, 115.0-114.8 (d, *J* = 22.2 Hz, 1 C), 110.2.

General procedure for synthesis of Substituted Quinolines:

2-Vinylanilines **1** (0.3 mmol) and 2-methylquinoline **2** (0.6 mmol) were mixed in 2mL of DMF and this mixture was carried out in the presence of 10 mol% $CuCl_2 \cdot 2H_2O$ and O_2. After being stirred at 130 ^oC for 32 h, the reaction mixture was cooled to room temperature and evaporated in vacuum. Then the crude product was purified by column chromatography, eluting with appropriate eluent to afford the desired quinolines **3**.

4-phenyl-2,2'-biquinoline (3aa). Yellow solid (44.8 mg, 71% yield); melting point: 191-194 ^oC; ^1H NMR (400 MHz, $CDCl_3$) δ 8.89-8.87 (d, *J* = 8.0 Hz, 1 H), 8.81 (s, 1 H), 8.33-8.28 (m, 2 H), 8.20-8.18 (d, *J* = 8.0 Hz, 1 H), 7.97-7.95 (m, 1 H), 7.87-7.85 (d, *J* = 8.0 Hz, 1 H), 7.75-7.71 (m, 2 H), 7.64-7.62 (m, 2 H), 7.58-7.49 (m, 5 H); $^{13}CNMR$ (100 MHz, $CDCl_3$) δ 156.3, 155.7, 149.2, 148.5, 148.0, 138.6, 136.7, 130.4, 130.0, 129.7, 129.5, 129.4, 128.53, 128.48, 128.3, 127.7, 127.02, 126.98, 126.94, 125.9, 119.7, 119.5; HRMS(ESI)*m/z* calcd for $C_{24}H_{17}N_2$ $[M+H]^+$ 333.1386, **found** 333.1377.

8-methyl-4-phenyl-2,2'-biquinoline (3ba). White solid (50.2 mg, 66% yield); melting point: 172-176 ^oC; ^1H NMR (400 MHz, $CDCl_3$) δ 9.01-9.00 (d, *J* = 8.0 Hz, 1 H), 8.86 (s, 1 H), 8.34-8.32 (d, *J* = 8.0 Hz, 1 H), 8.23-8.21 (d, *J* = 8.0 Hz, 1 H), 7.90-7.88 (d, *J* = 8.0 Hz, 1 H), 7.83-7.81 (d, *J* = 8.0 Hz, 1 H), 7.77-7.73 (m, 1 H), 7.66-7.64 (m, 3 H),

7.62-7.53 (m, 4 H), 7.44-7.41 (m, 1 H), 3.05 (s, 3 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.6, 154.0, 149.3, 147.9, 147.3, 139.0, 138.1, 136.5, 129.9, 129.8, 129.7, 129.5, 129.4, 128.43, 128.39, 128.1, 127.6, 126.9, 126.8, 126.6, 123.8, 119.5, 119.1, 18.4; HRMS(ESI)*m/z* calcd for $C_{25}H_{19}N_2$ $[M+H]^+$ 347.1543, **found** 347.1535.

6-methyl-4-phenyl-2,2'-biquinoline (3ca). White solid (39.1 mg, 47% yield); melting point: 179-182 °C; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.90-8.87 (d, *J* = 8.0 Hz, 1 H), 8.78 (s, 1 H), 8.35-8.33 (d, *J* = 8.0 Hz, 1 H), 8.22-8.19 (m, 2 H), 7.90-7.88 (d, *J* = 8.0 Hz, 1 H), 7.77-7.73 (m, 2 H), 7.67-7.54 (m, 7 H), 2.51 (s, 3 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.4, 154.9, 148.4, 147.9, 147.1, 138.8, 137.0, 136.6, 131.6, 130.1, 129.9, 129.7, 129.5, 128.5, 128.4, 128.2, 127.6, 127.0, 126.8, 124.6, 119.7, 119.4, 21.9; HRMS(ESI)*m/z* calcd for $C_{25}H_{19}N_2$ $[M+H]^+$ 347.1543, **found** 347.1537.

7,8-dimethyl-4-phenyl-2,2'-biquinoline (3da). White solid (59.8 mg, 83% yield); melting point: 232-234 °C; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.97-8.95 (d, *J* = 8.0 Hz, 1 H), 8.74 (s, 1 H), 8.31-8.29 (d, *J* = 8.0 Hz, 1 H), 8.18-8.16 (d, *J* = 8.0 Hz, 1 H), 7.86-7.84 (d, *J* = 8.0 Hz, 1 H), 7.73-7.68 (m, 2 H), 7.62-7.60 (m, 2 H), 7.56-7.49 (m, 4 H), 7.33-7.31 (d, *J* = 8.0 Hz, 1 H), 2.96 (s, 3 H), 2.54 (s, 3 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.9, 154.0, 149.2, 147.9, 147.2, 139.1, 137.0, 136.5, 135.3, 129.9, 129.8, 129.7, 129.4, 128.42, 128.37, 128.1, 127.6, 126.7, 125.3, 122.7,

119.6, 118.2, 20.6, 13.7; HRMS(ESI)*m/z* calcd for $C_{26}H_{21}N_2$ $[M+H]^+$ 361.1699, **found** 361.1689.

8-isopropyl-4-phenyl-2,2'-biquinoline (3ea). White solid (77.8 mg, 80% yield); melting point: 184-188 ^oC; ^1H NMR(400 MHz, $CDCl_3$) δ 8.96-8.93 (d, *J* = 8.6 Hz, 1 H), 8.81 (s, 1 H), 8.33-8.30 (d, *J* = 8.6 Hz, 1 H), 8.19-8.17 (d, *J* = 8.0 Hz, 1 H), 7.88-7.86 (d, *J* = 8.0 Hz, 1 H), 7.80-7.69 (m, 2 H), 7.66-7.45 (m, 8 H), 4.68-4.58 (m, 1 H), 1.54-1.51 (d, *J* = 4.0 Hz, 6 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.7, 153.8, 149.4, 148.0, 147.9, 146.1, 139.1, 136.5, 129.9, 129.7, 129.4, 128.41, 128.39, 128.1, 127.6, 127.0, 126.9, 126.8, 125.2, 123.5, 119.5, 119.0, 28.1, 23.6; HRMS(ESI)*m/z* calcd for $C_{27}H_{23}N_2$ $[M+H]^+$ 375.1856, **found** 375.1848.

6-isopropyl-4-phenyl-2,2'-biquinoline (3fa). Yellow solid (45.6 mg, 61% yield); melting point: 130-133 ^oC; ^1H NMR(300 MHz, $CDCl_3$) δ 8.88-8.85 (d, *J* = 8.4 Hz, 1 H), 8.76 (s, 1 H), 8.33-8.30 (d, *J* = 8.4 Hz, 1 H), 8.25-8.17 (m, 2 H), 7.88-7.85 (d, *J* = 8.0 Hz, 1 H), 7.76-7.64 (m, 5 H), 7.60-7.52 (m, 4 H), 3.09-3.00 (m, 1 H), 1.31-1.29 (d, *J* = 7.0 Hz, 6 H); ^{13}CNMR (75 MHz, $CDCl_3$) δ 156.5, 155.0, 148.7, 147.9, 147.8, 147.4, 138.8, 136.6, 130.3, 129.9, 129.7, 129.5, 128.9, 128.5, 128.4, 128.2, 127.6, 126.9, 126.8, 122.1, 119.7, 119.4, 34.4, 23.9; HRMS(ESI)*m/z* calcd for $C_{27}H_{23}N_2$ $[M+H]^+$ 375.1856, **found** 375.1844.

6-(tert-butyl)-4-phenyl-2,2'-biquinoline (3ga). White solid (27.0 mg, 41% yield); melting point: 151-155 ^oC; ^1H NMR(400 MHz, $CDCl_3$) δ

8.88-8.86 (d, *J* = 8.0 Hz, 1 H), 8.77 (s, 1 H), 8.33-8.31 (d, *J* = 8.0 Hz, 1 H), 8.24-8.17 (m, 2 H), 7.933-7.927 (d, *J* = 2.0 Hz, 1 H), 7.87-7.85 (m, 2 H), 7.73-7.70 (m, 1 H), 7.67-7.65 (m, 2 H), 7.60-7.52 (m, 4 H), 1.37 (s, 9 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.5, 155.2, 149.9, 149.0, 147.9, 147.0, 138.7, 136.6, 129.89, 129.85, 129.7, 129.5, 128.5, 128.4, 128.2, 127.6, 126.8, 126.5, 120.8, 119.7, 119.5, 35.2, 31.2; HRMS(ESI)*m/z* calcd for $C_{28}H_{25}N_2$ $[M+H]^+$ 389.2012, **found** 389.2000.

6-methoxy-4-phenyl-2,2'-biquinoline (3ha). White solid (35.5mg, 49% yield); melting point: 147-151 ^{o}C; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.85-8.83 (d, *J* = 8.4 Hz, 1 H), 8.75 (s, 1 H), 8.32-8.30 (d, *J* = 8.0 Hz, 1 H), 8.21-8.16 (m, 2 H), 7.87-7.85 (d, *J* = 8.0 Hz, 1 H), 7.75-7.63 (m, 3 H), 7.60-7.49 (m, 4 H), 7.44-7.40 (m, 1 H), 7.25-7.24 (d, *J* = 3.8 Hz, 1 H), 3.81 (s, 3 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 158.4, 156.4, 153.6, 148.0, 147.8, 144.6, 138.8, 136.6, 131.8, 129.8, 129.5, 129.4, 128.6, 128.33, 128.25, 128.0, 127.6, 126.7, 121.8, 120.0, 119.3, 103.9, 55.5; HRMS(ESI)*m/z* calcd for $C_{25}H_{19}N_2O$ $[M+H]^+$ 363.1492, **found** 363.1500

4,6-diphenyl-2,2'-biquinoline (3ia). Yellow solid (35.4 mg, 51% yield); melting point: 223-226 ^{o}C; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.91-8.89 (d, *J* = 8.0 Hz, 1 H), 8.83 (s, 1 H), 8.37-8.33 (m, 2 H), 8.21-8.15 (m, 2 H), 8.04-8.01 (m, 1 H), 7.89-7.87 (d, *J* = 8.0 Hz, 1 H), 7.74-7.72 (m, 1 H), 7.69-7.65 (m, 4 H), 7.61-7.51 (m, 4 H), 7.47-7.43 (m, 2 H), 7.38-7.35 (m, 1H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.2, 155.6, 149.3, 148.0, 147.9,

140.6, 139.7, 138.5, 136.7, 130.8, 130.0, 129.7, 129.5, 129.1, 128.9, 128.6, 128.5, 128.4, 127.7, 127.5, 127.2, 126.9, 123.6, 120.1, 119.5; HRMS(ESI)*m/z* calcd for $C_{30}H_{21}N_2$ $[M+H]^+$ 409.1699, **found** 409.1690.

8-fluoro-4-phenyl-2,2'-biquinoline (3ka). White solid (51.1 mg, 73% yield); melting point: 256-258 ^oC; ^1H NMR(400 MHz, $CDCl_3$) δ 8.96-8.94 (d, *J* = 8.0 Hz, 1 H), 8.88 (s, 1 H), 8.35-8.33 (d, *J* = 8.0 Hz, 1 H), 8.19-8.17 (d, *J* = 8.0 Hz, 1 H), 7.89-7.88 (d, *J* = 7.2 Hz, 1 H), 7.76-7.72 (m, 2 H), 7.63-7.61 (m, 2 h), 7.60-7.53 (m, 4 H), 7.46-7.43 (m, 2 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 158.7 (*J* = 250.0 Hz), 155.8, 155.7, 149.1 (*J* = 3.0 Hz), 147.9, 138.9 (*J* = 10.0 Hz), 138.3, 136.8, 129.9, 129.64, 129.57, 128.8, 128.6, 128.5, 127.7, 127.1, 126.5 (*J* = 10.0 Hz), 121.6 (*J* = 5.0 Hz), 120.5, 119.6, 113.5 (*J* = 20.0 Hz); HRMS(ESI)*m/z* calcd for $C_{24}H_{16}FN_2$ $[M+H]^+$ 351.1292, **found** 351.1285.

6-fluoro-4-phenyl-2,2'-biquinoline (3la). White solid (45.9 mg, 69% yield); melting point: 198-201 ^oC; ^1H NMR(400 MHz, $CDCl_3$) δ 8.86-8.83 (m, 2 H), 8.34-8.27 (m, 2 H), 8.19-8.17 (d, *J* = 8.0 Hz, 1 H), 7.89-7.87 (d, *J* = 8.0 Hz, 1 H), 7.76-7.72 (m, 1 H), 7.63-7.50 (m, 8 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 161.1 (*J* = 250.0 Hz), 156.0, 155.2, 148.7 (*J* = 10.0 Hz), 147.9, 145.6, 138.1, 136.8, 132.8 (*J* = 10.0 Hz), 129.9, 129.6, 129.5, 128.7, 128.6, 128.5, 127.9 (*J* = 10.0 Hz), 127.7, 127.0, 120.2, 119.6 (*J* = 20.0 Hz), 119.3, 109.3 (*J* = 20.0 Hz); HRMS(ESI)*m/z* calcd for $C_{24}H_{16}FN_2$ $[M+H]^+$ 351.1292, **found** 351.1287.

8-chloro-4-phenyl-2,2'-biquinoline (3ma). White solid (60.0 mg, 78% yield); melting point: 152-156 ^{o}C; ^{1}H NMR(400 MHz, $CDCl_3$) δ 9.06-9.03 (m, 1 H), 8.90-8.89 (d, *J* = 4.0 Hz, 1 H), 8.37-8.34 (m, 1 H), 8.19-8.17 (d, *J* = 8.0 Hz, 1 H), 7.90-7.86 (m, 3 H), 7.76-7.71 (m, 1 H), 7.62-7.51 (m, 6 H), 7.45-7.39 (m, 1 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 155.9, 155.8, 149.7, 147.9, 144.6, 138.3, 136.8, 134.6, 129.9, 129.7, 129.54, 129.5, 128.64, 128.6, 128.51, 128.5, 127.7, 127.1, 126.6, 125.0, 120.2, 119.8; HRMS(ESI)*m/z* calcd for $C_{24}H_{16}ClN_2$ $[M+H]^+$ 367.0997, **found** 367.0995.

6-chloro-4-phenyl-2,2'-biquinoline (3na). White solid (35.5 mg, 57% yield); melting point: 147-150 ^{o}C; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.86-8.83 (m, 2 H), 8.35-8.33 (d, *J* = 8.0 Hz, 1 H), 8.24-8.17 (m, 2 H), 7.93-7.87 (m, 2 H), 7.76-7.68 (m, 2 H), 7.63-7.54 (m, 6 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.0, 155.8, 148.4, 147.9, 146.9, 137.9, 136.8, 132.9, 131.9, 130.3, 130.0, 129.61, 129.6, 128.7, 128.6, 128.5, 127.7, 127.6, 127.1, 124.7, 120.4, 119.3; HRMS(ESI)*m/z* calcd for $C_{24}H_{16}ClN_2$ $[M+H]^+$ 367.0997, **found** 367.0992.

8-bromo-4-phenyl-2,2'-biquinoline (3oa). Yellow solid (51.1 mg, 89% yield); melting point: 188-193 ^{o}C; ^{1}H NMR(400 MHz, $CDCl_3$) δ 9.08-9.05 (m, 1 H), 8.89 (s, 1 H), 8.37-8.34 (m, 1 H), 8.19-8.17 (d, *J* = 8.0 Hz, 1 H), 8.11-8.08 (m, 1 H), 7.93-7.88 (m, 2 H), 7.76-7.71 (m, 1 H), 7.63-7.53 (m, 6 H), 7.38-7.32 (m, 1 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ

156.0, 155.8, 149.8, 147.9, 145.3, 138.2, 136.8, 133.1, 129.9, 129.7, 129.5, 128.7, 128.6, 128.52, 128.48, 127.7, 127.2, 127.1, 126.2, 125.8, 120.2, 119.9; HRMS(ESI)*m/z* calcd for $C_{24}H_{16}BrN_2$ $[M+H]^+$ 411.0492, **found** 411.0498.

6-bromo-4-phenyl-2,2'-biquinoline (3pa). White solid (46.6 mg, 71% yield); melting point: 197-199 ^oC; ^1H NMR(400 MHz, $CDCl_3$) δ 8.88-8.84 (m, 2 H), 8.36-8.34 (d, *J* = 8.0 Hz, 1 H), 8.21-8.16 (m, 2 H), 8.112-8.107 (d, *J* = 4.0 Hz, 1 H), 7.91-7.89 (d, *J* = 8.0 Hz, 1 H), 7.85-7.82 (m, 1 H), 7.77-7.74 (m, 1 H), 7.64-7.56 (m, 6 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.1, 155.8, 148.3, 147.9, 147.1, 137.9, 136.8, 132.9, 132.0, 130.0, 129.62, 129.6, 128.8, 128.6, 128.5, 128.2, 128.0, 127.7, 127.1, 121.2, 120.4, 119.3; HRMS(ESI)*m/z* calcd for $C_{24}H_{16}BrN_2$ $[M+H]^+$ 411.0492, **found** 411.0499.

6-bromo-4-(2-fluorophenyl)-2,2'-biquinoline (3qa). White solid (31.0 mg, 53% yield); melting point: 186-188 ^oC; ^1H NMR(400 MHz, $CDCl_3$) δ 8.89-8.87 (m, 2 H), 8.37-8.35 (d, *J* = 8.0 Hz, 1 H), 8.22-8.17 (m, 2 H), 7.91-7.84 (m, 3 H), 7.78-7.74 (m, 1 H), 7.62-7.53 (m, 3 H), 7.42-7.28 (m, 2 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 159.7 (*J* = 240.0 Hz), 156.1, 155.6, 147.9, 146.8, 142.5, 136.8, 133.1, 132.0, 131.8 (*J* = 3.0 Hz), 130.8 (*J* = 10.0 Hz), 129.9, 129.6, 128.5, 128.3, 127.9, 127.7, 127.1, 125.3 (*J* = 20.0 Hz), 124.6 (*J* = 4.0 Hz), 121.4, 121.3, 119.3, 116.2 (*J* = 20.0 Hz);

HRMS(ESI)*m/z* calcd for $C_{24}H_{15}BrFN_2$ $[M+H]^+$ 429.0397, **found** 429.0488.

6-chloro-4-(2-chlorophenyl)-2,2'-biquinoline (3ra). White solid (55.4 mg, 63% yield); melting point: 167-171 ^oC; ^1H NMR(400 MHz, $CDCl_3$) δ 8.88-8.85 (d, *J* = 8.8 Hz, 1 H), 8.81 (s, 1 H), 8.35-8.32 (d, *J* = 8.8 Hz, 1 H), 8.24-8.21 (d, *J* = 9.2 Hz, 1 H), 8.18-8.15 (d, *J* = 8.8 Hz, 1 H), 7.89-7.87 (d, *J* = 8.0 Hz, 1 H), 7.76-7.67 (m, 2 H), 7.63-7.45 (m, 6 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.0, 155.7, 147.9, 146.5, 145.8, 136.8, 136.6, 133.4, 133.1, 131.9, 131.5, 130.5, 130.1, 130.0, 129.9, 129.6, 128.5, 127.8, 127.6, 127.1, 127.0, 124.6, 120.9, 119.3; HRMS(ESI)*m/z* calcd for $C_{24}H_{15}Cl_2N_2$ $[M+H]^+$ 401.0607, **found** 401.0616.

4-phenyl-2-(quinolin-2-yl)benzo[h]quinoline (3sa). Yellow solid (55.1 mg, 76% yield); melting point: 232-234 ^oC; ^1H NMR(300 MHz, $CDCl_3$) δ 9.65-9.62 (d, *J* = 8.8 Hz, 1 H), 9.14-9.11 (d, *J* = 8.4 Hz, 1 H), 8.94 (s, 1 H), 8.40-8.37 (d, *J* = 8.0 Hz, 1 H), 8.21-8.19 (d, *J* = 8.0 Hz, 1 H), 7.94-7.54 (m, 13 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.6, 153.9, 149.2, 148.0, 146.4, 138.9, 136.6, 133.6, 132.1, 129.9, 129.8, 129.5, 128.53, 128.47, 128.3, 128.2, 128.0, 127.71, 127.65, 127.0, 126.8, 125.1, 124.8, 123.1, 120.3, 119.6; HRMS(ESI)*m/z* calcd for $C_{28}H_{19}N_2$ $[M+H]^+$ 383.1543, **found** 383.1536.

4-methyl-2,2'-biquinoline (3ta). Yellow solid (35.9mg, 38% yield); melting point: 119-122 ^oC; ^1H NMR(300 MHz, $CDCl_3$) δ 8.85-8.82 (d, *J*

= 8.0 Hz, 1 H), 8.68 (s, 1 H), 8.33-8.31 (d, *J* = 8.0 Hz, 1 H), 8.26-8.22 (m, 2 H), 8.07-8.04 (d, *J* = 8.0 Hz, 1 H), 7.90-7.87 (d, *J* = 8.4 Hz, 1 H), 7.79-7.72 (m, 2 H), 7.62-7.55 (m, 2 H), 2.85 (t, *J* = 0.6 Hz, 3 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.5, 155.8, 147.9, 147.8, 145.0, 136.7, 130.5, 129.9, 129.5, 129.2, 128.5, 128.4, 127.7, 126.9, 126.7, 123.8, 119.9, 119.5, 19.0; HRMS(ESI)*m/z* calcd for $C_{19}H_{15}N_2$ $[M+H]^+$ 271.1230, **found** 271.1227.

6'-methyl-4-phenyl-2,2'-biquinoline (3ab). White solid (42.7 mg, 65% yield); melting point: 163-167 ^oC; ^{1}H NMR(300 MHz, $CDCl_3$) δ 8.86-8.83 (d, *J* = 8.0 Hz, 1 H), 8.78 (s, 1 H), 8.31-8.23 (m, 2 H), 8.09-8.07 (d, *J* = 8.0 Hz, 1 H), 7.98-7.95 (d, *J* = 8.0 Hz, 1 H), 7.78-7.73 (m, 1 H), 7.65-7.62 (m, 3 H), 7.59-7.49 (m, 5 H), 2.57 (s, 3 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 155.9, 155.5, 149.1, 148.5, 146.5, 138.6, 136.9, 136.0, 131.8, 130.3, 129.7, 129.6, 129.3, 128.5, 128.3, 127.0, 126.9, 126.6, 125.8, 119.6, 119.5, 21.7; HRMS(ESI)*m/z* calcd for $C_{25}H_{19}N_2$ $[M+H]^+$ 347.1543, **found** 347.1539.

6'-methoxy-4-phenyl-2,2'-biquinoline (3ac). Yellow solid (37.1 mg, 54% yield); melting point: 138-143 ^oC; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.84-8.82 (d, *J* = 8.0 Hz, 1 H), 8.76 (s, 1 H), 8.29-8.27 (d, *J* = 8.0 Hz, 1 H), 8.22-8.20 (d, *J* = 8.0 Hz, 1 H), 8.09-8.06 (d, *J* = 9.2 Hz, 1 H), 7.96-7.94 (d, *J* = 8.0 Hz, 1 H), 7.76-7.72 (m, 1 H), 7.64-7.62 (m, 2 H), 7.58-7.48 (m, 4 H), 7.39-7.36 (m, 1 H), 7.13-7.12 (d, *J* = 4.0 Hz, 1 H),

3.94 (s, 3 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 158.2, 155.9, 154.0, 149.1, 148.5, 144.0, 138.6, 135.4, 131.4, 130.2, 129.7, 129.6, 129.3, 128.5, 128.3, 126.9, 126.8, 125.8, 122.3, 119.8, 119.5, 105.2, 55.6; HRMS(ESI)*m/z* calcd for $C_{25}H_{19}N_2O$ $[M+H]^+$ 363.1492, **found** 363.1483.

6'-fluoro-4-phenyl-2,2'-biquinoline (3ad). White solid (38.2 mg, 52% yield); melting point: 178-182 ^oC; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.92-8.90 (d, *J* = 8.0 Hz, 1 H), 8.76 (s, 1 H), 8.30-8.26 (m, 2 H), 8.20-8.16 (m, 1 H), 7.97-7.95 (d, *J* = 8.0 Hz, 1 H), 7.78-7.74 (m, 1 H), 7.64-7.62 (m, 2 H), 7.60-7.47 (m, 6 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 160.8 (*J* = 240.0 Hz), 155.8, 155.4, 149.2, 148.5, 145.0, 138.5, 136.0 (*J* = 10.0 Hz), 132.4 (*J* = 10.0 Hz), 130.3, 129.7, 129.4, 129.1 (*J* = 10.0 Hz), 128.5, 128.4, 127.0, 125.9, 120.2, 119.9, 119.6, 119.4, 110.7 (*J* = 22.0 Hz); HRMS(ESI)*m/z* calcd for $C_{24}H_{16}FN_2$ $[M+H]^+$ 351.1292, **found** 351.1289.

7'-fluoro-4-phenyl-2,2'-biquinoline (3ae). White solid (39.0 mg, 53% yield); melting point: 132-135 ^oC; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.86-8.84 (d, *J* = 8.0 Hz, 1 H), 8.77 (s, 1 H), 8.32-8.28 (m, 2 H), 7.98-7.96 (d, *J* = 8.0 Hz, 1 H), 7.87-7.74 (m, 3 H), 7.64-7.62 (m, 2 H), 7.59-7.51 (m, 4 H), 7.37-7.32 (m, 1 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 163.2 (*J* = 250.0 Hz), 157.2, 155.3, 149.3, 148.9 (*J* = 20.0 Hz), 148.5, 138.5, 136.6, 130.4, 129.7, 129.5 (*J* = 10.0 Hz), 129.4, 128.6, 128.4, 127.1 (*J* = 3.0 Hz), 125.9, 125.4, 119.6, 118.8 (*J* = 3.0 Hz), 117.5, 117.2,

113.5 (J = 20.0 Hz); HRMS(ESI)*m/z* calcd for $C_{24}H_{16}FN_2$ $[M+H]^+$ 351.1292, **found** 351.1295.

7'-chloro-4-phenyl-2,2'-biquinoline (3af). White solid (61.2 mg, 88% yield); melting point: 279-282 ^oC; ^1H NMR(400 MHz, $CDCl_3$) δ 8.89-8.87 (d, J = 8.0 Hz, 1 H), 8.76 (s, 1 H), 8.30-8.27 (m, 2 H), 8.193-8.188 (d, J = 1.6 Hz, 1 H), 7.98-7.96 (d, J = 8.0 Hz, 1 H), 7.81-7.74 (m, 2 H), 7.64-7.62 (m, 2 H), 7.59-7.49 (m, 5 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 157.2, 155.2, 149.3, 148.5, 148.3, 138.4, 136.5, 135.3, 130.4, 129.7, 129.5, 128.9, 128.8, 128.6, 128.4, 127.9, 127.2, 127.1, 126.8, 125.9, 119.7, 119.6; HRMS(ESI)*m/z* calcd for $C_{24}H_{16}ClN_2$ $[M+H]^+$ 367.0997, **found** 367.0987.

6'-bromo-4-phenyl-2,2'-biquinoline (3ag). Orange solid (54.2 mg, 63% yield); melting point: 207-210 ^oC; ^1H NMR(300 MHz, $CDCl_3$) δ 8.92-8.89 (d, J = 8.0 Hz, 1 H), 8.76 (s, 1 H), 8.30-8.22 (m, 2 H), 8.06-7.95 (m, 3 H),7.81-7.74 (m, 2 H), 7.64-7.51 (m, 6 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.6, 155.2, 149.3, 148.5, 146.5, 138.4, 135.7, 133.0, 131.6, 130.3, 129.7, 129.67, 129.5, 128.5, 128.4, 127.1, 127.0, 125.9, 120.8, 120.3, 119.5; HRMS(ESI)*m/z* calcd for $C_{24}H_{16}BrN_2$ $[M+H]^+$ 411.0492, **found** 411.0503.

3-(4-phenylquinolin-2-yl)benzo[f]quinoline (3ah). White solid (47.4 mg, 69% yield); melting point: 210-213 ^oC; ^1H NMR(300 MHz, $CDCl_3$) δ 9.16-9.13 (d, J = 8.0 Hz, 1 H), 9.04-9.01 (d, J = 8.0 Hz, 1 H), 8.84 (s, 1

H), 8.74-8.71 (d, *J* = 8.0 Hz, 1 H), 8.34-8.31 (d, *J* = 8.0 Hz, 1 H), 8.11-7.95 (m, 4 H), 7.80-7.51 (m, 8 H), 7.26 (s, 1 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 155.7, 155.6, 149.2, 148.6, 147.8, 138.6, 132.0, 131.5, 130.9, 130.3, 129.7, 129.4, 128.7, 128.6, 128.5, 128.3, 127.4, 127.1, 126.9, 125.9, 125.7, 123.0, 119.6, 119.56; HRMS(ESI)*m/z* calcd for $C_{28}H_{19}N_2$ $[M+H]^+$ 383.1543, **found** 383.1531.

4-phenyl-2-(pyridin-2-yl)quinoline (3ai). Yellow solid (20.0 mg, 34% yield); melting point: 138-142 ^oC; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.73-8.68 (m, 2 H), 8.52 (s, 1 H), 8.26-8.23 (m, 1 H), 7.97-7.93 (m, 1 H), 7.91-7.85 (m, 1 H), 7.76-7.71 (m, 1 H), 7.61-7.47 (m, 6 H), 7.39-7.32 (m, 1 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.4, 155.7, 149.3, 149.2, 148.5, 138.4, 136.9, 130.2, 129.7, 129.4, 128.5, 128.3, 126.8, 125.8, 124.0, 121.9, 119.3; HRMS(ESI)*m/z* calcd for $C_{20}H_{15}N_2$ $[M+H]^+$ 283.1230, **found** 283.1221.

2-(5-ethylpyridin-2-yl)-4-phenylquinoline (3aj). Yellow solid (41.1 mg, 51% yield); melting point: 153-155 ^oC; ^{1}H NMR(300 MHz, $CDCl_3$) δ 8.63-8.57 (m, 2 H), 8.51-8.50 (m, 1 H), 8.26-8.24 (d, *J* = 8.0 Hz, 1 H), 7.97-7.94 (d, *J* = 8.0 Hz, 1 H), 7.75-7.72 (m, 2 H), 7.62-7.48 (m, 6 H), 2.76 (q, *J* = 8.0 Hz, 2 H), 1.33 (m, 3 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 155.8, 154.1, 149.2, 148.9, 148.5, 139.9, 138.5, 136.3, 130.2, 129.7, 129.3, 128.4, 128.3, 126.7, 126.6, 125.8, 121.6, 119.2, 26.1, 15.3; HRMS(ESI)*m/z* calcd for $C_{22}H_{19}N_2$ $[M+H]^+$ 311.1543, **found** 311.1539.

4-phenyl-2,2'-biquinoline (3aa). Yellow solid (27.3 mg, 33% yield); melting point: 191-194 °C; ^{1}H NMR(300 MHz, $CDCl_3$) δ 8.90-8.87 (d, *J* = 8.4 Hz, 1 H), 8.81 (s, 1 H), 8.35-8.29 (m, 2 H), 8.21-8.18 (d, *J* = 8.4 Hz, 1 H), 7.98-7.95 (d, *J* = 8.4 Hz, 1 H), 7.89-7.86 (d, *J* = 8.0 Hz, 1 H), 7.79-7.71 (m, 2 H), 7.65-7.63 (m, 2 H), 7.60-7.50 (m, 5 H); ^{13}CNMR (75 MHz, $CDCl_3$) δ 156.2, 156.7, 149.1, 148.5, 147.9, 138.5, 136.7, 130.3, 129.9, 129.7, 129.5, 129.4, 128.5, 128.4, 128.3, 127.6, 127.0, 126.9, 125.8, 119.6, 119.4; HRMS(ESI)*m/z* calcd for $C_{24}H_{17}N_2$ $[M+H]^+$ 333.1386, **found** 333.1379.

8-methyl-4-phenyl-2,2'-biquinoline (3ba). White solid (44.8 mg, 55% yield); melting point: 172-176 °C; ^{1}H NMR(300 MHz, $CDCl_3$) δ 8.96-8.94 (d, *J* = 8.0 Hz, 1 H), 8.81 (s, 1 H), 8.30-8.27 (d, *J* = 8.4 Hz, 1 H), 8.18-8.16 (d, *J* = 8.0 Hz, 1 H), 7.86-7.83 (d, *J* = 8.0 Hz, 1 H), 7.79-7.76 (d, *J* = 8.4 Hz, 1 H), 7.73-7.68 (m, 1 H), 7.62-7.46 (m, 7 H), 7.40-7.35 (m, 1 H), 3.00 (s, 3 H); ^{13}CNMR (75 MHz, $CDCl_3$) δ 156.7, 154.1, 149.3, 147.9, 147.4, 139.1, 138.1, 136.5, 129.9, 129.8, 129.5, 129.4, 128.5, 128.4, 128.2, 127.6, 127.0, 126.8, 126.7, 123.8, 119.5, 119.2, 18.4; HRMS(ESI)*m/z* calcd for $C_{25}H_{19}N_2$ $[M+H]^+$ 347.1543, **found** 347.1533.

6-methyl-4-phenyl-2,2'-biquinoline (3ca). White solid (20.6 mg, 23% yield); melting point: 179-182 °C; ^{1}H NMR(300 MHz, $CDCl_3$) δ 8.90-8.87 (d, *J* = 8.0 Hz, 1 H), 8.77 (s, 1 H), 8.36-8.33 (d, *J* = 8.0 Hz, 1

H), 8.22-8.19 (m, 2 H), 7.91-7.89 (d, J = 8.0 Hz, 1 H), 7.75-7.72 (m, 2 H), 7.67-7.55 (m, 7 H), 2.52 (s, 3 H); ^{13}CNMR (75 MHz, $CDCl_3$) δ 156.4, 154.9, 148.4, 147.9, 147.0, 138.7, 137.0, 136.7, 131.6, 130.0, 129.9, 129.7, 129.5, 128.5, 128.4, 128.2, 127.6, 126.9, 126.8, 124.6, 119.7, 119.4; HRMS(ESI)*m/z* calcd for $C_{25}H_{19}N_2$ $[M+H]^+$ 347.1543, **found** 347.1535.

6-chloro-4-phenyl-2,2'-biquinoline (3na). White solid (17.4 mg, 19% yield); melting point: 147-150 ^{o}C; ^{1}H NMR(300 MHz, $CDCl_3$) δ 8.86-8.83 (m, 2 H), 8.35-8.32 (d, J = 8.0 Hz, 1 H), 8.24-8.17 (m, 2 H), 7.93-7.87 (m, 2 H), 7.77-7.67 (m, 2 H), 7.63-7.54 (m, 6 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 155.9, 155.8, 148.4, 147.9, 146.9, 137.8, 136.8, 132.9, 131.9, 130.3, 129.9, 129.6, 129.57, 128.7, 128.6, 128.5, 127.7, 127.7, 127.1, 124.7, 120.4, 119.3; HRMS(ESI)*m/z* calcd for $C_{24}H_{16}ClN_2$ $[M+H]^+$ 367.0997, **found** 367.0989.

General Procedure for Synthesis of Substituted Fused Heterocyclic Compounds 5:

2-Arylanilines **1** (0.3 mmol) and 2-methylquinoline **6** (0.6 mmol) were mixed in 2 mL of DMF and this mixture was carried out in the presence of 10 mol% $CuCl_2 \cdot 2H_2O$ and O_2. After being stirred at 130 ^{o}C for 32 h, the reaction mixture was cooled to room temperature and evaporated in vacuum. Then the crude product was purified by column chromatography, eluting with appropriate eluent to afford the desired quinolines **5**.

4-(quinolin-2-yl)pyrrolo[1,2-a]quinoxaline (5aa). Yellow solid (69.9 mg, 75% yield); melting point: 190-192 ^{o}C; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.64-8.62 (d, *J* = 8.0 Hz, 1 H), 8.33-8.27 (m, 2 H), 8.12-8.01 (m, 3 H), 7.91-7.87 (m, 2 H), 7.80-7.74 (m, 1 H), 7.62-7.44 (m, 3 H), 7.01-6.99 (m, 1 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.2, 150.9, 147.5, 136.4, 135.7, 130.5, 130.1, 129.5, 128.3, 128.2, 127.7, 127.6, 127.2, 125.1, 124.7, 120.6, 114.6, 114.3, 113.7, 111.2; HRMS(ESI)*m/z* calcd for $C_{20}H_{14}N_3$ $[M+H]^+$ 296.1182, **found** 296.1179.

4-(6-methylquinolin-2-yl)pyrrolo[1,2-a]quinoxaline (5ab). Yellow solid (63.4 mg, 65% yield); melting point: 182-182 ^{o}C; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.58-8.56 (m, 1 H), 8.22-8.16 (m, 2 H), 8.10-8.07 (m, 2 H), 8.01-8.00 (m, 1 H), 7.89-7.87 (m, 1 H), 7.62-7.57 (m, 2 H), 7.54-7.50 (m, 1 H), 7.47-7.43 (m, 1 H), 7.00-6.98 (m, 1 H), 2.56 (s, 3 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 155.4, 151.0, 146.1, 137.3, 135.7, 135.6, 131.8, 130.4, 129.7, 128.3, 128.1, 127.7, 126.5, 125.0, 124.7, 120.6, 114.5, 114.2, 113.7, 111.2, 21.7; HRMS(ESI)*m/z* calcd for $C_{21}H_{16}N_3$ $[M+H]^+$ 310.1339, **found** 310.1344.

4-(6-fluoroquinolin-2-yl)pyrrolo[1,2-a]quinoxaline (5ad). Yellow solid (79.0 mg, 80% yield); melting point: 194-196 ^{o}C; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.68-8.66 (d, *J* = 8.0 Hz, 1 H), 8.30-8.25 (m, 2 H), 8.10-8.03 (m, 3 H), 7.93-7.91 (m, 1 H), 7.59-7.46 (m, 4 H), 7.02-7.00 (m, 1 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 161.7 (*J*= 248.0 Hz), 156.4, 151.2, 145.3,

136.42, 136.37, 133.3 (*J*= 10.0 Hz), 131.2, 129.7 (*J*= 10.0 Hz), 129.0, 128.5, 125.9, 125.3, 122.0, 120.5 (*J*= 25.0 Hz), 115.2 (*J*= 26.0 Hz), 114.4, 111.8, 111.4 (*J*= 22.0 Hz) HRMS(ESI)*m/z* calcd for $C_{20}H_{13}FN_3$ $[M+H]^+$ 314.1088, **found** 314.1082.

4-(7-fluoroquinolin-2-yl)pyrrolo[1,2-a]quinoxaline (5ae). Yellow solid (88.0 mg, 89% yield); melting point: 203-205 ^oC; ^1H NMR(300 MHz, $CDCl_3$) δ 8.62-8.59 (d, *J* = 8.0 Hz, 1 H), 8.31-8.28 (d, *J* = 8.0 Hz, 1 H), 8.10-8.02 (m, 3 H), 7.92-7.84 (m, 3 H), 7.59-7.53 (m, 1 H), 7.50-7.45 (m, 1 H), 7.42-7.35 (m, 1 H), 7.02-7.00 (m, 1 H); ^{13}CNMR (75 MHz, $CDCl_3$) δ 163.1 (*J*= 240.0 Hz), 157.2, 150.5, 148.4 (*J*= 12.0 Hz), 136.2, 135.6, 130.5, 129.5 (*J*= 20.0 Hz), 128.3, 127.7, 125.2 (*J*= 11.0 Hz), 124.6, 119.98 (*J*= 2.0 Hz), 117.8, 117.5, 114.6, 114.3, 113.7, 113.4, 111.1; HRMS(ESI)*m/z* calcd for $C_{20}H_{13}FN_3$ $[M+H]^+$ 314.1088, **found** 314.1091.

7-methyl-4-(quinolin-2-yl)pyrrolo[1,2-a]quinoxaline (5ba). Yellow solid (63.6 mg, 77% yield); melting point: 192-192 ^oC; ^1H NMR(400 MHz, $CDCl_3$) δ 8.62-8.60 (d, *J* = 8.0 Hz, 1 H), 8.30-8.27 (m, 2 H), 8.08-8.07 (m, 1 H), 7.96-7.95 (m, 1 H), 7.87-7.85 (d, *J* = 8.0 Hz, 2 H), 7.78-7.74 (m, 2 H), 7.60-7.56 (m, 1 H), 7.34-7.31 (m, 1 H), 6.97-6.96 (m, 1 H), 2.50 (s, 3 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 157.0, 151.5, 148.2, 137.0, 136.3, 135.5, 130.9, 130.8, 130.2, 130.0, 128.9, 128.3, 127.9, 126.3, 125.3, 121.3, 114.9, 114.7, 114.1, 115.6, 21.7; HRMS(ESI)*m/z* calcd for $C_{21}H_{16}N_3$ $[M+H]^+$ 310.1339, **found** 310.1345.

8-methoxy-4-(quinolin-2-yl)pyrrolo[1,2-a]quinoxaline (5ca). Yellow solid (59.5 mg, 65% yield); melting point: 174-177 ^{o}C; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.63-8.61 (d, *J* = 8.0 Hz, 1 H), 8.31-8.27 (m, 2 H), 8.11-8.10 (m, 1 H), 8.025-8.003 (d, *J* = 8.8 Hz, 1 H), 7.93-7.87 (m, 2 H), 7.79-7.75 (m, 1 H), 7.61-7.57 (m, 1 H), 7.31-7.30 (d, *J* = 4.0 Hz, 1 H), 7.09-7.06 (m, 1 H), 7.02-7.00 (m, 1 H), 3.97 (s, 3 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 159.8, 156.4, 148.4, 147.6. 136.2, 131.9, 130.2, 130.1, 129.5, 128.6, 128.2, 127.6, 127.1, 124.7, 120.5, 114.7, 113.7, 113.0, 110.7, 94.7, 55.8; HRMS(ESI)*m/z* calcd for $C_{21}H_{16}N_3O$ $[M+H]^+$ 326.1288, **found** 326.1278.

8-fluoro-4-(quinolin-2-yl)pyrrolo[1,2-a]quinoxaline (5da). Yellow solid (53.4 mg, 63% yield); melting point: 206-208 ^{o}C; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.62-8.60 (d, *J* = 8.0 Hz, 1 H), 8.34-8.27 (m, 2 H), 8.13-8.12 (m, 1 H), 8.09-8.06 (m, 1 H), 7.91-7.89 (d, *J* = 8.0 Hz, 2 H), 7.81-7.76 (m, 1 H), 7.63-7.56 (m, 2 H), 7.26-7.18 (m, 1 H), 7.04-7.02 (m, 1 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 161.9 (*J* = 248.0 Hz), 156.0, 150.1, 147.5, 136.4, 132.4 (*J* = 10.0 Hz), 130.0, 129.6, 128.3, 127.6, 127.3, 124.4, 120.4, 115.1, 114.4, 113.1 (*J* = 23.0 Hz), 111.5, 100.7, 100.4, 98.6 (*J* = 4.0 Hz); HRMS(ESI)*m/z* calcd for $C_{20}H_{13}FN_3$ $[M+H]^+$ 314.1088, **found** 314.1083.

9-chloro-4-(quinolin-2-yl)pyrrolo[1,2-a]quinoxaline (5ea). Yellow solid (49.0 mg, 52% yield); melting point: 218-220 ^{o}C; ^{1}H NMR(400

MHz, $CDCl_3$) δ 8.62-8.60 (d, *J* = 8.0 Hz, 1 H), 8.35-8.28 (m, 2 H), 8.16-8.15 (m, 1 H), 8.09-8.08 (d, *J* = 4.0 Hz, 1 H), 8.004-7.995 (m, 1 H), 7.91-7.89 (d, *J* = 8.0 Hz, 1 H), 7.85-7.77 (m, 2 H), 7.64-7.60 (m, 1 H), 7.52-7.49 (m, 1 H), 7.03-7.01 (m, 1 H); ^{13}CNMR (100 MHz, $CDCl_3$) δ 156.5, 152.5, 148.2, 137.4, 137.2, 130.9, 130.8, 130.5, 130.3, 129.1, 128.8, 128.3, 128.2, 127.1, 125.3, 121.2, 115.7, 115.6, 115.3, 112.6; HRMS(ESI)*m/z* calcd for $C_{20}H_{13}ClN_3$ $[M+H]^+$ 330.0793, **found** 330.0783.

8-chloro-6-fluoro-4-(quinolin-2-yl)pyrrolo[1,2-a]quinoxaline (5fa). Yellow solid (23.6 mg, 26% yield); melting point: 223-225 ^oC; ^{1}H NMR(300 MHz, $CDCl_3$) δ 8.69-8.66 (d, *J* = 8.0 Hz, 1 H), 8.32-8.24 (m, 3 H), 7.92-7.87 (m, 2 H), 7.81-7.75 (m, 1 H), 7.67-7.59 (m, 2 H), 7.25-7.19 (m, 1 H), 7.05-7.03 (m, 1 H); ^{13}CNMR (75 MHz, $CDCl_3$) δ 158.9 (*J* = 250.0 Hz), 155.7, 150.7, 147.5, 136.4, 133.3 (*J* = 20.0 Hz), 130.1, 129.6, 129.3, 128.4, 127.6 (*J* = 10.0 Hz), 124.7, 120.7, 115.7, 114.9, 112.9, 112.3 (*J* = 20.0 Hz), 109.9 (*J*= 3.0 Hz); HRMS(ESI)*m/z* calcd for $C_{20}H_{12}ClFN_3$ $[M+H]^+$ 348.0698, **found** 348.0688.

4-phenyl-2-(pyridin-4-yl)quinoline (7aa).[22] Yellow solid (60.9 mg, 72% yield); melting point: 137-139 ^oC; ^{1}H NMR(400 MHz, $CDCl_3$) δ 8.78-8.76 (m, 2 H), 8.27-8.25 (m, 1 H), 8.09-8.08 (m, 2 H), 7.94-7.92 (m, 1 H), 7.83 (s, 1 H), 7.78-7.74 (m, 1 H), 7.57-7.50 (m, 6 H); ^{13}CNMR (75 MHz, $CDCl_3$) δ 153.9, 150.4, 149.8, 148.8, 146.6, 137.9, 130.3, 129.9,

129.5, 128.7, 128.6, 127.2, 126.4, 125.7, 121.6, 118.7; HRMS(ESI)*m/z* calcd for $C_{20}H_{15}N_2$ $[M+H]^+$ 283.1230, **found** 282.1233.

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Supporting Information NMR spectra of all compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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