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Synthesis of 3,4-Disubstituted Quinolin-2-(1*H*)-ones *via* Palladium-Catalyzed Decarboxylative Arylation Reactions

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Abstract: The Pd-catalyzed decarboxylative cross-coupling reaction of 4-substituted quinolin-2(1*H*)-one-3-carboxylic acids with (hetero)aryl halides is described. With palladium(II) bromide and triphenylarsine ligand as the catalyst system, a variety of 4-substituted 3-(hetero)aryl quinolin-2(1*H*)-ones and related heterocycles, such as 4-substituted 3-arylcoumarins can be prepared in good to excellent yields.

Keywords: aryl halides; decarboxylative arylation; palladium catalysis; 4-substituted 3-(hetero)arylquinolin-2(1*H*)-ones

Introduction

4-Substituted 3-(hetero)arylquinolin-2(1*H*)-ones represent an important class of fused heterocyclic compounds regarding their various pharmacological properties including antiviral,[1] antibacterial[2] and anticancer[3] activities. Examples of biologically active agents[4] containing this structural motif are depicted in Figure 1.

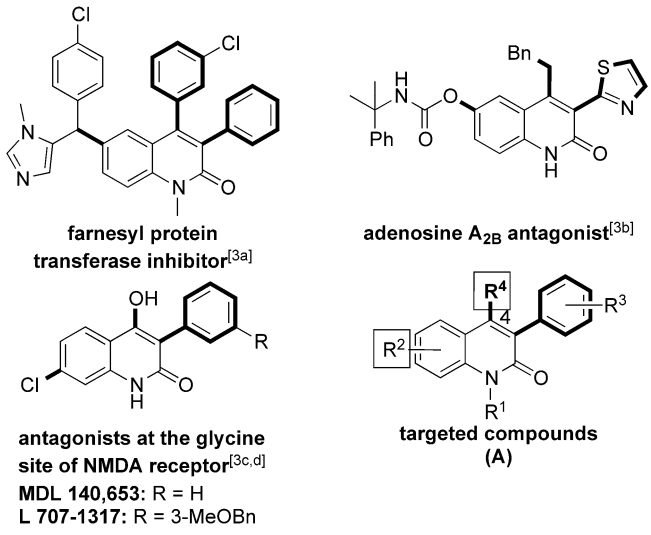
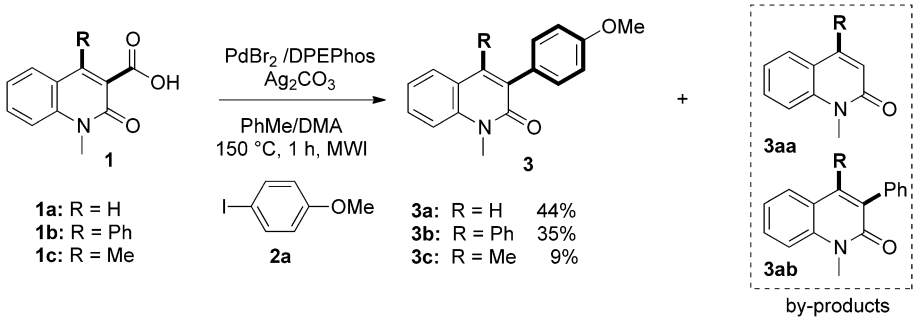


Figure 1. Chemical structures of bioactive 3,4-disubstituted quinolin-2(1*H*)-ones.

Traditional strategies for the preparation of 3,4-disubstituted quinolin-2(1*H*)-ones involve the construction of the heterocycle rings by non-trivial multistep reaction sequences.[2,4,5] In recent years, efforts to develop new approaches to 3,4-disubstituted quinolin-2(1*H*)-ones under transition metal catalysis have been reported, including the site-selective palladium-catalyzed Suzuki cross-coupling of 3-bromo-4-tosylquinolin-2(1*H*)-one with arylboronic acids.[6] However, this reaction requires the use of stoichiometric amounts of organometallic compounds, thus generating waste from reagents. Alternative routes involve C–H activation/annulation of *N*-arylpropiolamides[7] under Pd catalysis, tandem Pd-catalyzed amidation/aldol condensation of aryl halides having an *ortho* carbonyl functional group with 2-phenylacetamide,[8] or annulation of *N*-arylcarbamoyl chlorides with internal alkynes under Ir catalysis.[9] Although these methods are suitable procedures, they are often moderate to low yielding and suffer from issues of poor regioselectivity,[7,8] thus limiting the substrate scope. Therefore, it is of great interest to develop general and convergent protocols for the synthesis 3,4-disubstituted quinolin-2(1*H*)-ones.

In support of an ongoing medicinal chemistry program directed toward antagonists of the *N*-methyl-D-aspartate (NMDA) receptor,[10] we required the synthesis of 4-substituted 3-(hetero)arylquinolin-2(1*H*)-ones of type **A**. Their preparation was envisioned through palladium-catalyzed decarboxylative arylation of 4-substituted quinolin-2(1*H*)-one-3-carboxylic



Scheme 1. Pd-catalyzed decarboxylative coupling of **2a** with **1a–c** under our previously optimized conditions.

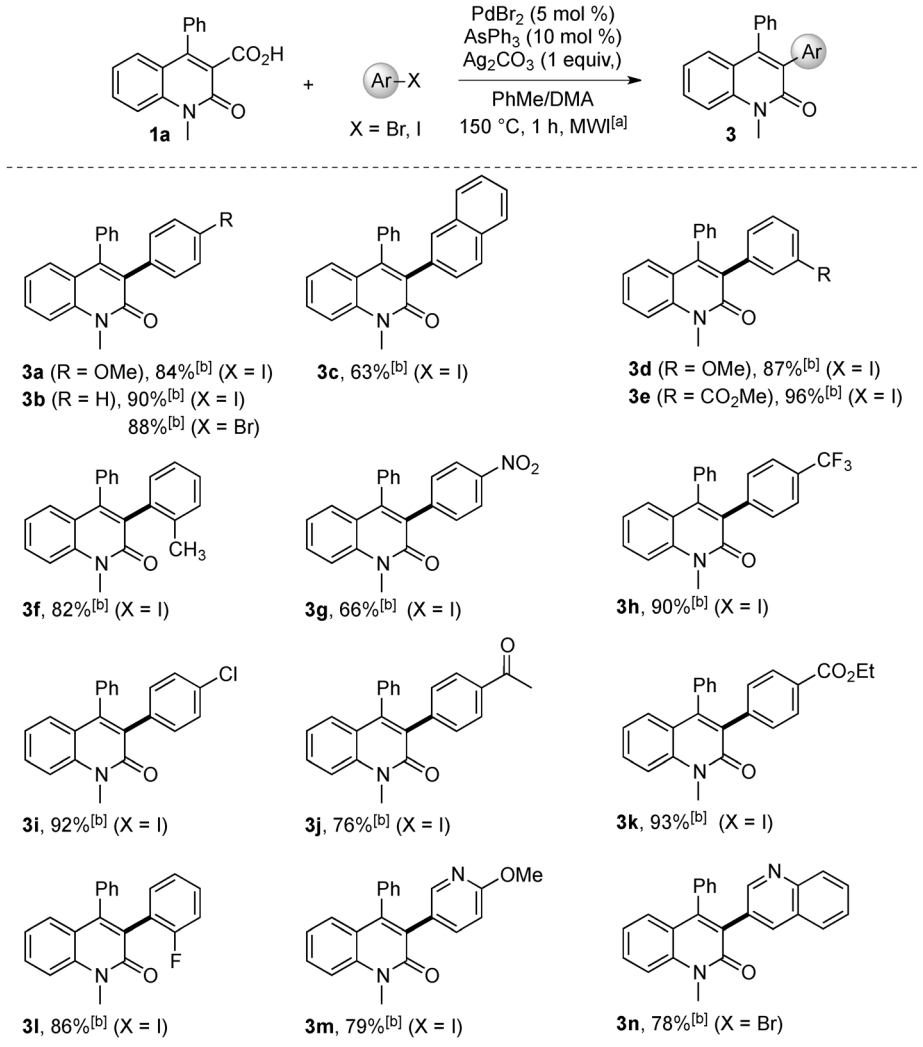
acids. Such a procedure which generates minimum waste upon decarboxylation, places this transformation[11] amongst the greenest alternatives to traditional cross-couplings. Despite the great success of this reaction in the coupling of σ electron-poor benzoic acids with aryl halides for biaryl synthesis,[12] the corresponding coupling with heterocyclic carboxylic acids, has received much less attention. In this area, very recently, we have reported a highly efficient and versatile decarboxylative coupling reaction of quinolin-4(1*H*)-one-3-carboxylic acids[13] with (hetero)aryl halides. The bimetallic system composed of $PdBr_2$/DPEphos/Ag_2CO_3 enables high-yielding reactions with various (hetero)aryl halides. In addition, we demonstrated through a preliminary result that the use of these conditions also enabled, for the first time, decarboxylative arylation of quinolin-2(1*H*)-one-3-carboxylic acid **1a** to provide **3a** in an acceptable 44% yield (Scheme 1). However, according to this protocol,[13] all our attempts to prepare **3b**, **c** by coupling **1b**, **c** with **2a** resulted in unsatisfactory yields. The targeted 4-substituted 3-(4-methoxyphenyl)quinolin-2(1*H*)-ones **3b**, **c** were formed in yields never exceeding 35%, regardless of the nature of the substituent at the C-4 position of the quinolin-2(1*H*)-one moiety (Scheme 1). Two others by-products were obtained as a mixture: (i) quinolinones **3aa** derived from protodecarboxylation of **1** and (ii) compounds **3ab** which resulted from the phenyl migration from the phosphine ligand.[14]

Our attempts to increase the yields of **3b**, **c** by using high catalyst loading (up to 15 mol%) and elevated temperatures (up to 170 °C) combined with a prolonged reaction times did not lead to any improvement. These unsuccessful results clearly demonstrate that the nature of the heterocyclic substrate and its substituent at the C-4 position play a critical role in the outcome of this decarboxylative coupling reaction. To address difficulties associated with the reactivity of 4-substituted quinolin-2(1*H*)-one-3-carboxylic acids **1**, we decided to investigate this challenging coupling reaction by fine-tuning of the palladium source and ligand. The results of this study are now reported.

Results and Discussion

After considerable exploration of the reaction parameters (for more details, see the Supporting Information), optimal conditions for the coupling of 4-phenylquinolin-2(1*H*)-one-3-carboxylic acid **1a** with **2a**, as the model study, required the use of $PdBr_2$ (5 mol%), $AsPh_3$ (10 mol%) and Ag_2CO_3 (1 equiv.), toluene/DMA (9:1) in a sealed Schlenk tube at 150 °C for 1 h under microwave irradiation. Accordingly, the desired coupling product **3a** was isolated in a good 84% yield (Scheme 2). It should be noted that carrying out the reaction using traditional oil bath heating (150 °C, 1 h, sealed tube), induced a lowering of the conversion rate, and **3a** was isolated in only 74% yield. This result clearly demonstrated the benefit to use microwave irradiation.

With this promissing result in hand, we started to investigate the substrate scope for the Pd-catalyzed decarboxylative coupling of **1a** with various (hetero)-aryl halides possessing different steric and electronic properties. As illustrated in Scheme 2, both aryl iodides and bromides reacted well providing the desired compound **3b** in excellent yields. Electron-rich and electron-deficient, *meta* and *para* substituted aryl halides all underwent efficiently the decarboxylative coupling with **1a** in good yields (products **3a–e** and **3g–k**). In addition, the sterically demanding *ortho* substitution pattern was tolerated toward coupling reaction of **1a**, leading to 4-phenyl-3-arylquinolin-2(1*H*)-ones **3f** and **3l** in yields up to 82%, regardless of the electronic nature of the substituents. Interestingly, product **3i** revealed excellent chemical selectivity preserving the C–Cl bond, which could undergo further metal-catalyzed functionalization processes.[15] In addition, reactions of **1a** with aryl iodides bearing an enolizable methyl ketone or ethoxycarbonyl functions were also efficient furnishing in good yields the coupling products **3e**, **3j** and **3k**, which could then be subject to fur-

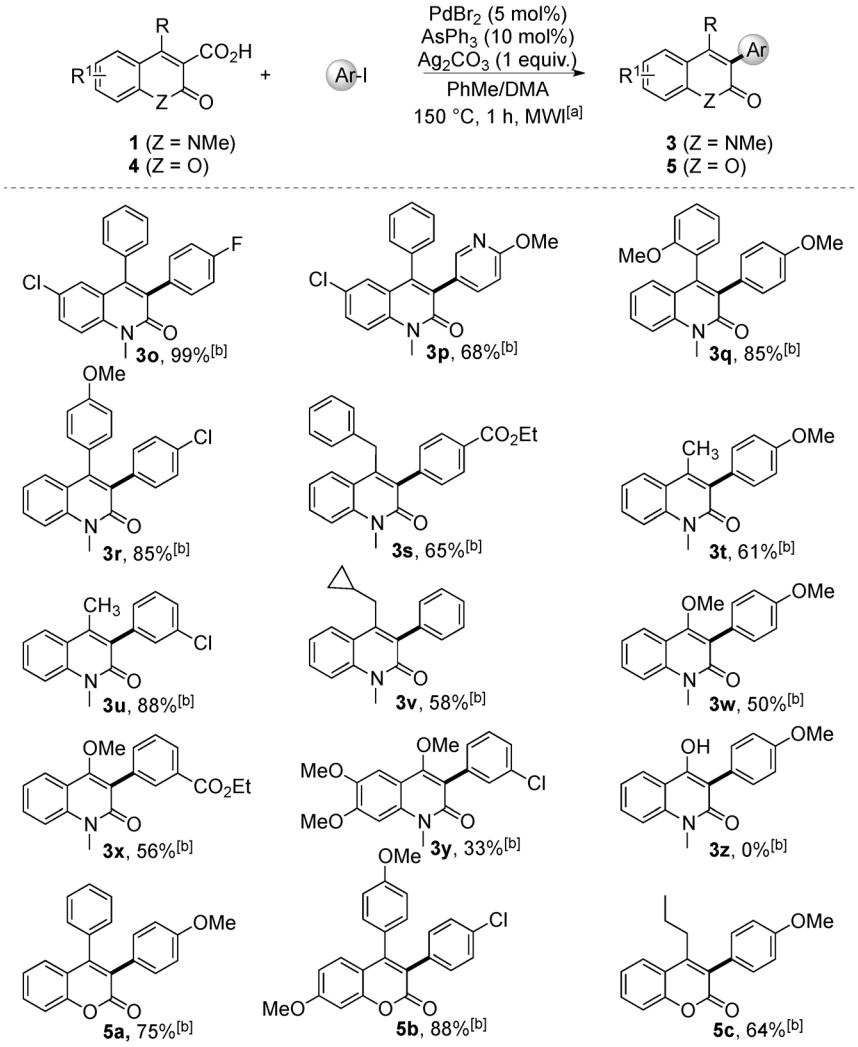


[a] Reactions of **1** (1 equiv.) with ArX (2 equiv.) were performed under MWI in a sealed Schlenk tube at 150 °C in toluene/DMA 9:1 (0.05 M) by using $PdBr_2$ (5 mol%), $AsPh_3$ (10 mol%) and Ag_2CO_3 (1 equiv.).
[b] Yield of isolated product.

Scheme 2. Pd-catalyzed decarboxylative coupling of **1a** with various (hetero)aryl halides.

ther synthetic transformations. Heteroaromatic halides could be employed in this coupling reaction as well. Thus, 3-iodo-6-methoxypyridine and 3-bromoquinoline gave rise the heteroarylated quinolin-2-(1*H*)-ones **3m**, **n** in 79% and 78 yields, respectively.

Motivated by these results, we then examined under our optimized conditions the efficiency of this catalytic system on the coupling of a range of quinolin-2(1*H*)-one-3-carboxylic acids containing other important groups at the C-4 position or on the aromatic ring of the quinolin-2(1*H*)-one moeity. As summarized in Scheme 3, all the substrates studied efficiently undergo the coupling reaction with various aryl halides under the $PdBr_2$/$AsPh_3$ catalytic system, providing the corresponding 3,4-disubstituted quinolin-2(1*H*)-one products in yields ranging from 33 to 99%. We were pleased to observe that this procedure is compatible with a wide range of substituents at the C-4 position of the quinolin-2-one moiety such as aryl, alkyl and benzyl groups, clearly indicating that the reaction does not seems to be sensitive to steric hindrance. In this way, excellent yields of (hetero)arylated quinolin-2(1*H*)-ones **3o–u** were obtained. Moreover, the presence of base-sensitive substituents on the C-4 position such cyclopropylmethyl as well as a methoxy group[17] on substrates **3v–y** were tolerated under our catalytic system, however, the yields decrease slightly. Noteworthy, the reaction is not effective with quinolin-2(1*H*)-one-3-carboxylic acid bearing a free hydroxy group at the C-4 position. In this case, compound **3z** has never been obtained and only a mixture of protodecarboxylative by-product and



[a] Reactions of heterocyclic carboxylic acid (1 equiv) with ArI (2 equiv) were performed under MWI in a sealed Schlenk tube at 150 °C in toluene/DMA 9:1 (0.05 M) by using $PdBr_2$ (5 mol%), $AsPh_3$ (10 mol %) and Ag_2CO_3 (1 equiv.).
[b] Yield of isolated product.

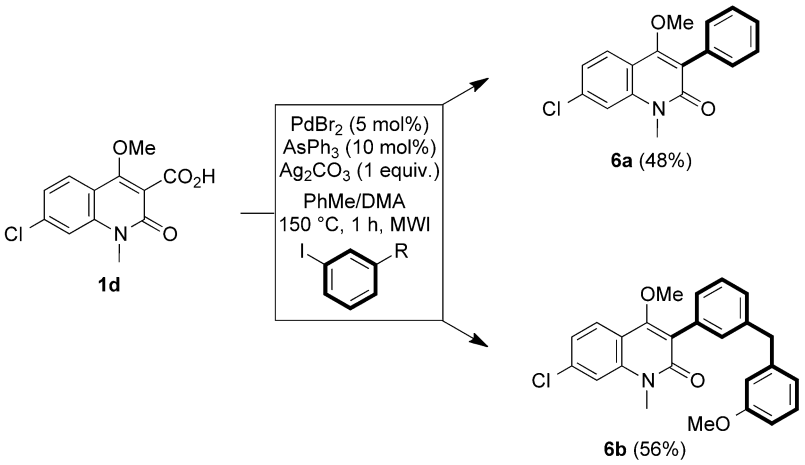
Scheme 3. Pd-catalyzed decarboxylative coupling of quinolin-2(1*H*)-one-carboxylic acid derivatives[16] with various (hetero)-aryl iodides.

starting materials was isolated. Next, we used this catalytic system in decarboxylative coupling of other heterocyclic carboxylic acids. Overall, this system could be successfully applied to 4-substituted coumarin-3-carboxylic acids,[18] leading to 3,4-disubstituted coumarins **5a-c** in yields ranging from 65% to 88%, regardless of the nature of the aryl halide partner.

Finally, to illustrate the synthetic potential of our protocol, substrate **1d** enables the synthesis of *N*-methylated 3-arylquinolin-2(1*H*)-ones **6a**, **b** related to MDL 140,653 and L 707-1317 as potential antagonists at the glycine site of the NMDA receptor (Scheme 4). The key step was the coupling of **1d** with iodobenzene and 1-iodo-3-(3-methoxybenzyl)benzene under our optimized conditions to give selectively 4-methoxy-3-arylquinolin2(1*H*)-ones **6a** and **6b** in 48% and 56% yields, respectively.

Conclusions

In conclusion, we have developed an efficient and practical $PdBr_2/AsPh_3$ catalytic system for the decarboxylative coupling of various 4-substituted quinolin-2(1*H*)-one-3-carboxylic acids with (hetero)aryl halides. This transformation exhibited broad substrate scope with respect to both the heterocyclic carboxylic acids and (hetero)aryl halides. It provides an attractive alternative to the existing methods for the synthesis of 4-substituted 3-(hetero)arylquinolin-2(1*H*)-ones



Scheme 4. Synthesis of **6a**, **b**, as analogues of MDL 140,653 and L 707-1317.

3 and related heterocycles **5** of biological interest. We believe that this methodology should find broad applications in synthetic organic chemistry, as well as in the combinatorial and pharmaceutical sciences.

Experimental Section

General Experimental Methods

The compounds were all identified by the usual physical methods, that is, ^{1}H NMR, ^{13}C NMR (J-MOD), IR, MS (ESI). ^{1}H and ^{13}C NMR spectra were measured in $CDCl_3$ or DMSO-d_6 with a Bruker Avance-300. ^{1}H NMR chemical shifts are reported in ppm from an internal standard TMS or of residual chloroform (7.27 ppm). The following abreviations are used: m (multiplet), s (singlet), bs (broad singlet), d (doublet), t (triplet) dd (doublet of doublet), td (triplet of doublet), q (quadruplet), qui (quintuplet), sex (sextuplet). ^{13}C NMR chemical shifts are reported in ppm from the central peak of deuteriochloroform (77.14). IR spectra were measured on a Bruker Vector 22 spectrophotometer. Mass spectra were recorded on a Micromass spectrometer. Analytical TLC was performed on Merck precoated silica gel 60F plates. Merck silica gel 60 (0.015–0.040 mm) was used for column chromatography. Melting points were recorded on a Büchi B-450 apparatus and are uncorrected.

General Procedure for Palladium-Catalyzed Decarboxylative Coupling

A flame-dried resealable 2–5 mL Pyrex reaction vessel was charged with the solid reactant(s): $PdBr_2$ (5.0 mol%), $AsPh_3$ (10 mol%), heterocyclic carboxylic acid (1 equiv.), (hetero)-aryl halide (2 equiv.) and Ag_2CO_3 (1 equiv.). The reaction vessel was capped with a rubber septum, evacuated and backfilled with argon; this evacuation/backfill sequence was repeated one additional time. The liquid reactant(s) and toluene/DMA (9:1, 0.05 M) were added through the septum. The septum was replaced with a Teflon screwcap. The reaction vessel was sealed, then placed in the Emrys Optimizer and exposed to microwave irradiation according to the following specifications: temperature: 150 °C; 1 h; fixed hold time: on; high absorption: high; pre-stirring: 60 s. The resulting suspension was cooled to room temperature and filtered through a pad of Celite eluting with ethyl acetate, and the inorganic salts were removed. The filtrate was washed with water. The aqueous layer was extracted twice with EtOAc. The combined organic layers were washed with a saturated solution of NH_4Cl then brine, dried over $MgSO_4$, filtered and evaporated under reduced pressure. The residue was purified by flash chromatography over silica gel to afford the desired product.

Analytical Data for 4-Substituted 3-(Hetero)arylquinolin-2(1*H*)-ones 3

***3-(4-Methoxyphenyl)-1-methyl-4-phenylquinolin-2(1H)-one* (3a):** Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and 1-iodo-4-methoxybenzene (234 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 80:20) to afford the desired product **3a** as a beige solid; yield: 143 mg, 0.42 mmol (84%); R_f 0.27 (cyclohexane/ethyl acetate 70:30); mp 165 °C (recrystallized from ethyl acetate to give beige crystals). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.56$ (t, $J = 7.8$ Hz, 1H), 7.44 (d, $J = 8.4$ Hz, 1H), 7.30–7.26 (m, 4H), 7.14–7.10 (m, 3H), 7.03 (d, $J = 8.4$ Hz, 2H), 6.70 (d, $J = 8.7$ Hz, 2H), 3.85 (s, 3H), 3.73 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 162.2$, 158.4, 147.5, 139.6, 136.7, 132.0 (2C), 131.7, 130.2, 130.0 (2C), 128.5, 128.3, 128.1 (2C), 127.6, 121.9, 121.7, 114.1, 113.1 (2C), 55.2, 30.3; IR (film): $\nu =$ 1640, 1601, 1512, 1458, 1312, 1291,1248, 1177 cm^{-1}; HR-MS (ES$^+$): $m/z = 364.1310$, calculated for $C_{23}H_{19}NO_2Na$ $[M+Na]^+$: 364.1313.

***1-Methyl-3,4-diphenylquinolin-2(1H)-one* (3b):**[19] Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and iodobenzene (204 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 80:20) to afford the desired product **3b** as a beige solid; yield: 140 mg, 0.45 mmol (90%); R_f 0.36

(cyclohexane/ethyl acetate 70:30), mp 220 °C (recrystallized from ethyl acetate to give white crystals). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.58$ (t, $J = 8.1$ Hz, 1H), 7.46 (d, $J = 8.4$ Hz, 1H), 7.32–7.24 (m, 4H), 7.19–7.09 (m, 8H), 3.86 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 161.9$, 147.8, 139.6, 136.4, 136.0, 132.1, 130.7 (2C), 130.4, 130.0 (2C), 128.6, 128.0 (2C), 127.6, 127.5 (2C), 127.0, 122.0, 121.6, 114.1, 30.20; IR (film): $\nu = 1630$, 1601, 1589, 1457, 1311 cm^{-1}.

***1-Methyl-3-(naphthalen-2-yl)-4-phenylquinolin-2(1H)-one* (3c):** Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and 2-iodo-4-naphthalene (254 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 80:20) to afford the desired product **3c** as an orange solid,; yield: 113 mg, 0.31 mmol (63%); R_f 0.37 (cyclohexane/ethyl acetate 70:30); mp 211 °C (recrystallized from ethyl acetate to give pale orange crystals). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta =$ 7.73–7.70 (m, 1H), 7.66–7.57 (m, 4H), 7.48 (d, $J = 8.4$ Hz, 1H), 7.41–7.32 (m, 3H), 7.27–7.12 (m, 7H), 3.88 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 162.1$, 148.1, 139.7, 136.4, 133.6, 133.1, 132.4, 132.0, 130.5, 130.2, 130.0 (2C), 128.7, 128.6, 128.2 (2C), 127.7, 127.6, 127.0, 125.8, 125.6, 122.1, 121.7, 114.2, 30.3; IR (film): $\nu = 1640$, 1600, 1313 cm^{-1}; HR-MS (ES$^+$): $m/z = 384.1362$, calculated for $C_{26}H_{19}NONa$ [M + Na]$^+$: 384.1364.

***3-(3-Methoxyphenyl)-1-methyl-4-phenylquinolin-2(1H)-one* (3d):** Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and 1-iodo-3-methoxybenzene (234 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 70:30) to afford the desired product **3d** as a beige solid; yield: 148.1 mg, 0.43 mmol (87%); R_f 0.27 (cyclohexane/ethyl acetate 70:30); mp 146 °C (recrystallized from ethyl acetate to give beige crystals). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.58$ (t, $J = 8.4$ Hz, 1H), 7.45 (d, $J = 8.4$ Hz, 1H), 7.32–7.26 (m, 4H), 7.15–7.06 (m, 4H), 6.74–6.63 (m, 2H), 3.85 (s, 3H), 3.63 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 161.8$, 158.9, 147.8, 139.7, 137.3, 136.5, 132.0, 130.4, 129.9 (2C), 128.6, 128.5, 128.1 (2C), 127.7, 123.4, 122.0, 121.6, 116.1, 114.2, 113.2, 55.2, 30.2, IR (film) ν 1639, 1601, 1461, 1287, 1253, 1212, 1049; HR-MS (ES$^+$): $m/z = 364.1307$, calculated for $C_{23}H_{19}NO_2Na$ [M + H]$^+$: 364.1313.

***Ethyl 3-(1-methyl-2-oxo-4-phenyl-1,2-dihydroquinolin-3-yl)benzoate* (3e):** Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and ethyl 3-iodobenzoate (275 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 80:20) to afford the desired product **3e** as a beige solid; yield: 184 mg, 0.48 mmol (96%); R_f 0.30 (cyclohexane/ethyl acetate 70:30); mp 154–155 °C (recrystallized from ethyl acetate to give beige crystals): ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.76$–7.73 (m, 2H), 7.55–7.49 (m, 1H), 7.39 (d, $J = 8.4$ Hz, 1H), 7.24–7.13 (m, 6H), 7.09–7.02 (m, 3H), 4.22 (q, $J = 7.2$ Hz, 2H), 3.78 (s, 3H), 1.26 (t, $J = 7.2$ Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 166.6$, 161.7, 148.4, 139.7, 136.3, 136.1, 135.2, 132.1, 131.1, 130.7, 129.9 (2C), 128.7, 128.3, 128.2 (2C), 127.9, 127.7, 122.2, 121.5, 114.2, 60.9, 30.3, 14.4; IR (film): $\nu = 1715$, 1635, 1602, 1313, 1291, 1262, 1226 cm^{-1}; HR-MS (ES$^+$): $m/z = 406.1420$, calculated for $C_{25}H_{21}NO_3Na$ [M + Na]$^+$: 406.1419.

***1-Methyl-4-phenyl-3-(o-tolyl)quinolin-2(1H)-one* (3f):** Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and 1-iodo-2-methylbenzene (218 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 80:20) to afford the desired product **3f** as a beige solid; yield: 134 mg, 0.41 mmol (82%); R_f 0.39 (cyclohexane/ethyl acetate 70:30); mp 195 °C (recrystallized from ethyl acetate to give beige crystals). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.59$ (t, $J = 7.8$ Hz, 1H), 7.48 (d, $J = 8.4$ Hz, 1H), 7.31–7.12 (m, 6H), 7.08–6.95 (m, 4H), 6.90 (d, $J = 7.2$ Hz, 1H), 3.86 (s, 3H), 2.17 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 161.4$, 148.1, 139.9, 136.8, 136.4, 136.0, 132.5, 130.6, 130.4, 130.1, 129.6, 128.6, 128.4, 128.2, 127.8, 127.8, 127.5, 125.3, 122.0, 121.6, 114.2, 30.2, 20.1; IR (film): $\nu = 1640$, 1601, 1459, 1312 cm^{-1}; HR-MS (ES$^+$): $m/z =$ 348.1361, calculated for $C_{23}H_{19}NONa$ [M + Na]$^+$: 348.1364.

***1-Methyl-3-(4-nitrophenyl)-4-phenylquinolin-2(1H)-one* (3g):** Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and 1-iodo-4-nitrobenzene (248 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 80:20) to afford the desired product **3g** as a yellow solid; yield: 117 mg, 0.33 mmol (66%); R_f 0.28 (cyclohexane/ethyl acetate 70:30); mp 216 °C (recrystallized from ethyl acetate to give pale yellow crystals). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta =$ 8.03 (d, $J = 8.4$ Hz, 2H), 7.63 (t, $J = 7.5$ Hz, 1H), 7.49 (d, $J =$ 8.1 Hz, 1H), 7.31–7.28 (m, 6H), 7.17 (t, $J = 7.2$ Hz, 1H), 7.11–7.08 (m, 2H), 3.86 (s, 3H), ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 161.1$, 148.9, 146.7, 143.4, 139.9, 135.6, 131.9 (3C), 131.3, 129.8 (2C), 128.9, 128.5 (2C), 128.3, 122.8 (2C), 122.4, 121.2, 114.4, 30.3, IR (film): $\nu = 1631$, 1602, 1588, 1515, 1314, 1236 cm^{-1}; HR-MS (ES$^+$): $m/z = 379.1053$, calculated for $C_{22}H_{16}N_2O_3Na$ [M + H]$^+$: 379.1059.

***1-Methyl-4-phenyl-3-[4-(trifluoromethyl)phenyl]quinolin-2(1H)-one* (3h):** Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and 1-iodo-4-(trifluoromethyl)benzene (272 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 90:10 to 80:20) to afford the desired product **3h** as an off-white solid; yield: 170.6 mg, 0.45 mmol (90%); R_f 0.32 (cyclohexane/ethyl acetate 70:30); mp 196 °C (recrystallized from ethyl acetate to give white crystals). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.64$–7.58 (m, 1H), 7.48 (d, $J =$ 8.4 Hz, 1H), 7.43 (d, $J = 8.1$ Hz, 2H), 7.33–7.27 (m, 4H), 7.23 (d, $J = 8.1$ Hz, 2H), 7.15 (t, $J = 7.2$ Hz, 1H), 7.11–7.08 (m, 2H), 3.86 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta =$ 161.5, 148.5, 140.0, 139.8, 135.9, 131.2 (2C), 130.9, 130.7, 129.9 (2C), 129.0 (q, $J = 32$ Hz), 128.8, 128.3 (2C), 128.1, 124.5 (2C, q, $J = 3.75$ Hz), 124.3 (q, $J = 271$ Hz), 122.3, 121.4, 114.3, 30.3, ^{19}F NMR (188 MHz, $CDCl_3$): $\delta = -63.0$; IR (film): $\nu = 1639$, 1602, 1491, 1458, 1264 cm^{-1}; HR-MS (ES$^+$):

$m/z = 402.1085$, calculated for $C_{23}H_{16}NOF_3Na$ $[M+Na]^+$: 402.1082.

***3-(4-Chlorophenyl)-1-methyl-4-phenylquinolin-2(1H)-one* (3i):** Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and 1-chloro-4-iodobenzene (238.5 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 80:20) to afford the desired product **3i** as a white solid; yield: 159.1 mg, 0.46 mmol (92%); R_f 0.41 (cyclohexane/ethyl acetate 70:30); mp 202 °C (recrystallized from ethyl acetate to give white crystals). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.59$ (t, $J = 7.2$ Hz, 1H), 7.46 (d, $J = 8.7$ Hz, 1H), 7.31–7.28 (m, 4H), 7.16–7.08 (m, 5H), 7.05 (d, $J = 8.4$ Hz, 2H), 3.85 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 161.7$, 148.2, 139.7, 136.2, 134.6, 132.9, 132.2 (2C), 130.9, 130.7, 129.9 (2C), 128.7, 128.3 (2C), 127.9, 127.8 (2C), 122.1, 121.5, 114.2, 30.3; IR (film): $\nu = 1635$, 1601, 1491, 1458, 1313, 1090 cm^{-1}; HR-MS (ES$^+$): $m/z = 368.0836$, calculated for $C_{22}H_{16}NONa^{35}Cl$ $[M+Na]^+$: 368.0818.

***3-(4-Acetylphenyl)-1-methyl-4-phenylquinolin-2(1H)-one* (3j):** Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and 1-(4-iodophenyl)ethanone (246 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 70:30) to afford the desired product **3j** as a yellow solid; yield: 134 mg, 0.38 mmol (76%); R_f 0.15 (cyclohexane/ethyl acetate 70:30); mp 196 °C (recrystallized from ethyl acetate to give beige crystals). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.76$ (d, $J = 8.1$ Hz, 2H), 7.60 (t, $J = 7.8$ Hz, 1H), 7.47 (d, $J = 8.4$ Hz, 1H), 7.33–7.26 (m, 4H), 7.22 (d, $J = 8.1$ Hz, 2H), 7.16 (d, $J = 7.5$ Hz, 1H), 7.12–7.09 (m, 2H), 3.86 (s, 3H), 2.53 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 198.0$, 161.5, 148.3, 141.4, 139.8, 136.0, 135.6, 131.1 (2C), 131.0, 130.8, 129.9 (2C), 128.7, 128.3 (2C), 128.0, 127.7, 122.2, 121.4, 114.3, 30.2, 26.7; IR (film): $\nu = 1680$, 1633, 1602, 1458, 1363, 1313, 1268; HR-MS (ES$^+$): $m/z = 376.1313$, calculated for $C_{24}H_{19}NO_2Na$ $[M+Na]^+$: 376.1313.

***Ethyl 4-(1-methyl-2-oxo-4-phenyl-1,2-dihydroquinolin-3-yl)benzoate* (3k):** Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and ethyl 4-iodobenzoate (275 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 80:20) to afford the desired product **3k** as an off-white solid; yield: 177.5 mg, 0.46 mmol (93%); R_f 0.29 (cyclohexane/ethyl acetate 70:30); mp 165 °C (recrystallized from ethyl acetate to give white crystals): ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.85$ (d, $J = 8.1$ Hz, 2H), 7.60 (t, $J = 7.8$ Hz, 1H), 7.47 (d, $J = 8.4$ Hz, 1H), 7.32–7.26 (m, 3H), 7.20–7.08 (m, 6H), 4.32 (q, $J = 7.2$ Hz, 2H), 3.85 (s, 3H), 1.35 (t, $J = 7.2$ Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 166.7$, 161.5, 148.3, 141.1, 139.8, 136.0, 131.2, 130.9 (2C), 130.8, 129.9 (2C), 128.9, 128.8 (2C), 128.7, 128.3 (2C), 128.0, 122.2, 121.4, 114.3, 60.9, 30.2, 14.4; IR (film): $\nu = 1712$, 1632, 1602, 1589, 1271, 1101 cm^{-1}; HR-MS (ES$^+$): $m/z = 406.1416$, calculated for $C_{25}H_{21}NO_3Na$ $[M+Na]^+$: 406.1419.

***3-(2-Fluorophenyl)-1-methyl-4-phenylquinolin-2(1H)-one* (3l):** Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and 1-fluoro-2-iodobenzene (222 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 80:20) to afford the desired product **3l** as a white solid; yield: 141.2 mg, 0.43 mmol (86%); R_f 0.42 (cyclohexane/ethyl acetate 70:30); mp 192 °C (recrystallized from ethyl acetate to give white crystals). ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 7.62$–7.58 (m, 1H), 7.47 (d, $J = 6.0$ Hz, 1H), 7.32–7.25 (m, 4H), 7.16–7.14 (m, 4H), 7.01–6.91 (m, 3H), 3.86 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 161.2$, 160.4 (d, $J = 244$ Hz), 149.6, 140.0, 136.1, 132.3 (d, $J = 3.0$ Hz), 130.8, 129.5, 129.4 (d, $J = 8.0$ Hz), 129.2, 128.7, 128.4, 128.0, 127.8, 127.1, 124.3 (d, $J = 17$ Hz), 123.6 (d, $J = 3.0$ Hz), 122.1, 121.4, 115.2 (d, $J = 22$ Hz), 30.2; ^{19}F NMR (188 MHz, $CDCl_3$): δ −113.4; IR (film): $\nu = 1636$, 1602, 1323, 1163, 1123, 1070 cm^{-1}; HR-MS (ES$^+$): $m/z = 352.1113$, calculated for $C_{22}H_{16}NOFNa$ $[M+Na]^+$: 352.1114.

***3-(6-Methoxypyridin-3-yl)-1-methyl-4-phenylquinolin-2(1H)-one* (3m):** Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and 5-iodo-2-methoxypyridine (235 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 80:20) to afford the desired product **3m** as a yellow oil; yield: 134 mg, 0.39 mmol (78%); R_f 0.27 (cyclohexane/ethyl acetate 70:30). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.86$ (s, 1H), 7.57 (t, $J = 7.8$ Hz, 1H), 7.45–7.40 (m, 2H), 7.33–7.27 (m, 4H), 7.14–7.11 (m, 3H), 6.58 (d, $J = 8.4$ Hz, 1H), 3.84 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 162.8$, 161.8, 148.5, 148.4, 141.1, 139.6, 136.2, 130.6 (2C), 129.9 (2C), 128.6, 128.4 (2C), 127.9, 125.0, 122.1, 121.5, 114.2, 109.6, 53.5, 30.3; IR (film): $\nu = 1634$, 1602, 1493, 1285 cm^{-1}; HR-MS (ES$^+$): $m/z = 343.1428$, calculated for $C_{22}H_{19}N_2O_2$ $[M+H]^+$: 343.1441.

***1-Methyl-4-phenyl-3,3′-biquinolin-2(1H)-one* (3n):** Following the general procedure for decarboxylative coupling, a mixture of 1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1a** (139.5 mg, 0.5 mmol) and 3-bromoquinoline (208 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 80:20) to afford the desired product **3n** as a pale yellow solid; yield: 141 mg, 0.39 mmol (78%); R_f 0.11 (cyclohexane/ethyl acetate 70:30); mp 207–209 °C (recrystallized from ethyl acetate to give pale yellow crystals). ^{1}H NMR (300 MHz, $CDCl_3$):; $\delta = 8.64$ (d, $J = 1.8$ Hz, 1H), 8.11–8.08 (m, 2H), 7.71–7.62 (m, 3H), 7.52–7.47 (m, 2H), 7.36 (d, $J = 7.8$ Hz, 1H), 7.28–7.25 (m, 2H), 7.21–7.16 (m, 4H), 3.89 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 152.1$, 149.4, 146.4 (2C), 139.9, 138.3, 135.8, 131.1, 130.0 (2C), 129.6, 129.4, 128.9 (2C), 128.8, 128.6 (2C), 128.3, 128.1, 127.5, 126.5, 122.4, 121.5, 114.4, 30.4 (CO not observed); IR (film): $\nu = 2924$, 1634, 1600, 1490, 1313 cm^{-1}; HR-MS (ES$^+$): $m/z = 363.1496$, calculated for $C_{25}H_{19}N_2O$ $[M+H]^+$: 363.1497.

***6-Chloro-3-(4-fluorophenyl)-1-methyl-4-phenylquinolin-2(1H)-one* (3o):** Following general procedure for decarboxylative coupling, a mixture of 6-chloro-1-methyl-2-oxo-4-

phenyl-1,2-dihydroquinoline-3-carboxylic acid **1b** (156.75 mg, 0.5 mmol) and 1-fluoro-4-iodobenzene (222 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 80:20) to afford the desired product **3o** as an off-white solid; yield: 180 mg, 0.49 mmol (99%); R_f 0.31 (cyclohexane/ethyl acetate 70:30); mp 191 °C (recrystallized from ethyl acetate to give white crystals). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.44 (dd, J = 2.4–9.9 Hz, 1H), 7.29 (d, J = 9.0 Hz, 1H), 7.25–7.17 (m, 4H), 7.01–6.96 (m, 4H), 6.77 (t, J = 8.7 Hz, 2H), 3.74 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 161.9 (d, J = 244 Hz), 161.6, 147.1, 138.2, 135.6, 132.4 (d, J = 8.25 Hz, 2C), 132.2, 131.5 (d, J = 3.75 Hz), 130.6, 129.8 (2C), 128.5 (2C), 128.2, 127.8, 127.7, 122.7, 115.7, 114.7 (d, J = 22 Hz, 2C), 30.5, IR (film): ν = 1640, 1601, 1510, 1489, 1230 cm^{-1}; HR-MS (ES$^+$): m/z = 364.0911, calculated for $C_{22}H_{16}NOF^{35}Cl$ $[M+H]^+$: 364.0904.

6-Chloro-3-(6-methoxypyridin-3-yl)-1-methyl-4-phenylquinolin-2(1H)-one **(3p):** Following the general procedure for decarboxylative coupling, a mixture of 6-chloro-1-methyl-2-oxo-4-phenyl-1,2-dihydroquinoline-3-carboxylic acid **1b** (156.75 mg, 0.5 mmol) and 5-iodo-2-methoxypyridine (235 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 80:20 to 60:40) to afford the desired product **3p** as a yellow oil; yield: 128.5 mg, 0.34 mmol (68%); R_f 0.24 (cyclohexane/ethyl acetate 70:30). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.85 (d, J = 2.1 Hz, 1H), 7.50 (dd, J = 2.4–9.0 Hz, 1H), 7.41–7.30 (m, 5H), 7.23 (d, J = 2.1 Hz, 1H), 7.11–7.08 (m, 2H), 6.58 (d, J = 8.4 Hz, 1H), 3.84 (s, 3H), 3.80 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 162.9, 161.5, 148.4, 147.5, 141.0, 138.2, 135.5, 130.6, 129.8 (2C), 128.7 (2C), 128.3, 127.8, 127.7, 124.6, 122.7, 115.7, 109.7, 53.5, 30.5; IR (film): ν = 1634, 1601, 1488, 1284, 1026 cm^{-1}; HR-MS (ES$^+$): m/z = 377.1060, calculated for $C_{22}H_{18}N_2O_2^{35}Cl$ $[M+H]^+$: 377.1057.

4-(2-Methoxyphenyl)-3-(4-methoxyphenyl)-1-methylquinolin-2(1H)-one **(3q):** Following the general procedure for decarboxylative coupling, a mixture of 4-(2-methoxyphenyl)-1-methyl-2-oxo-1,2-dihydroquinoline-3-carboxylic acid **1c** (154.5 mg, 0.5 mmol) and 1-iodo-4-methoxybenzene (234 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 80:20) to afford the desired product **3q** as an off-white solid; yield: 157.7 mg, 0.42 mmol (85%); R_f 0.18 (cyclohexane/ethyl acetate 70:30); mp 168 °C (recrystallized from ethyl acetate to give white crystals). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.53 (t, J = 7.2 Hz, 1H), 7.42 (d, J = 8.4 Hz, 1H), 7.28–7.18 (m, 2H), 7.12–7.06 (m, 3H), 6.98–6.94 (m, 1H), 6.90–6.83 (m, 2H), 6.69 (d, J = 8.7 Hz, 2H) 3.84 (s, 3H), 3.72 (s, 3H), 3.62 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 162.2, 158.5, 156.8, 144.9, 139.5, 132.3, 131.2 (2C), 131.1, 130.0, 129.5, 128.8, 128.0, 125.9, 121.9, 121.6, 120.5, 114.1, 112.9 (2C), 110.8, 55.5, 55.2, 30.2; IR (film): ν = 1636, 1606, 1513, 1491, 1461, 1312, 1291, 1247, 1177, 1027; HR-MS (ES$^+$): m/z = 372.1603, calculated for $C_{24}H_{22}NO_3$ $[M+H]^+$: 372.1600.

3-(4-Chlorophenyl)-4-(4-methoxyphenyl)-1-methylquinolin-2(1H)-one **(3r):** Following the general procedure for decarboxylative coupling, a mixture of 4-(4-methoxyphenyl)-1-methyl-2-oxo-1,2-dihydroquinoline-3-carboxylic acid **1d** (154.5 mg, 0.5 mmol) and 1-chloro-4-iodobenzene (238.5 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 80:20) to afford the desired product **3r** as an off-white solid; yield: 159 mg, 0.42 mmol (85%); R_f 0.37 (cyclohexane/ethyl acetate 70:30); mp 197 °C (recrystallized from ethyl acetate to give white crystals): ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.58 (t, J = 7.2 Hz, 1H), 7.44 (d, J = 8.4 Hz, 1H), 7.35 (d, J = 7.5 Hz, 1H), 7.17–7.12 (m, 3H), 7.05 (d, J = 8.4 Hz, 2H), 7.00 (d, J = 8.7 Hz, 2H), 6.83 (d, J = 8.7 Hz, 2H), 3.84 (s, 3H), 3.81 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 161.7, 159.1, 148.0, 139.7, 134.8, 132.8, 132.2 (2C), 131.2 (2C), 131.0, 130.6, 128.7, 128.3, 127.9 (2C), 122.1, 121.8, 114.2, 113.8 (2C), 55.3, 30.2; IR (film): ν = 1634, 1598, 1513, 1495, 1456, 1314, 1176 cm^{-1}; HR-MS (ES$^+$): m/z = 398.0924, calculated for $C_{23}H_{18}NO_2Na^{35}Cl$ $[M+Na]^+$: 398.0924.

Ethyl 4-(4-benzyl-1-methyl-2-oxo-1,2-dihydroquinolin-3-yl)benzoate **(3s):** Following the general procedure for decarboxylative coupling, a mixture of 4-benzyl-1-methyl-2-oxo-1,2-dihydroquinoline-3-carboxylic acid **1e** (146.5 mg, 0.5 mmol) and ethyl 4-iodobenzoate (275 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 80:20) to afford the desired product **3s** as a yellow solid; yield: 129 mg, 0.32 mmol (65%); R_f 0.28 (cyclohexane/ethyl acetate 70:30); mp 98 °C (precipitated from ethyl acetate/hexane to give a white powder). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.05 (d, J = 8.1 Hz, 2H), 7.65 (d, J = 8.1 Hz, 1H), 7.55 (t, J = 8.1 Hz, 1H), 7.43 (d, J = 8.4 Hz, 1H), 7.34 (d, J = 8.4 Hz, 2H), 7.26–7.12 (m, 4H), 7.04 (d, J = 7.5 Hz, 2H), 4.37 (q, J = 7.2 Hz, 2H), 4.12 (s, 2H), 3.81 (s, 3H), 1.38 (t, J = 7.2 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 166.6, 161.6, 144.1, 141.4, 139.9, 138.9, 133.3, 130.6, 129.9 (2C), 129.6, 128.8, 128.0, 127.2, 126.5, 122.4, 120.6, 114.6, 61.1, 36.0, 30.2, 14.5; IR (film): ν = 2979, 1713, 1634, 1593, 1453, 1271, 1101 cm^{-1}; HR-MS (ES$^+$): m/z = 420.1573, calculated for $C_{26}H_{23}NO_3Na$ $[M+Na]^+$: 420.1576.

3-(4-Methoxyphenyl)-1,4-dimethylquinolin-2(1H)-one **(3t):** Following the general procedure for decarboxylative coupling, a mixture of 1,4-dimethyl-2-oxo-1,2-dihydroquinoline-3-carboxylic acid **1f** (108.5 mg, 0.5 mmol) and 1-iodo-4-methoxybenzene (234 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 90:10 to 80:20) to afford the desired product **3t** as a beige solid; yield: 85 mg, 0.30 mmol (61%); R_f 0.19 (cyclohexane/ethyl acetate 70:30); mp 141 °C (recrystallized from ethyl acetate to give beige crystals). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.81 (d, J = 7.8 Hz, 1H), 7.58 (t, J = 8.1 Hz, 1H), 7.40 (d, J = 8.4 Hz, 1H), 7.28 (t, J = 7.8 Hz, 1H), 7.20 (d, J = 8.7 Hz, 2H), 6.98 (d, J = 8.7 Hz, 2H), 3.86 (s, 3H), 3.77 (s, 3H), 2.35 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 162.0, 159.0, 142.3, 139.1, 132.1, 131.4 (2C), 130.0, 129.0, 125.7, 122.0, 121.7, 114.2, 113.7 (2C), 55.4, 29.9, 17.0; IR (film): ν = 1635, 1608, 1513, 1461, 1312, 1290, 1245 cm^{-1}; HR-MS (ES$^+$): m/z = 302.1158, calculated for $C_{18}H_{17}NO_2Na$ $[M+Na]^+$: 302.1157.

3-(3-Chlorophenyl)-1,4-dimethylquinolin-2(1H)-one **(3u):** Following the general procedure for decarboxylative coupling, a mixture of 1,4-dimethyl-2-oxo-1,2-dihydroquinoline-3-carboxylic acid **1f** (108.5 mg, 0.5 mmol) and 1-chloro-3-iodobenzene (238.5 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15) to afford the desired product **3u** as a beige solid; yield: 124.5 mg, 0.44 mmol (88%); R_f

0.34 (cyclohexane/ethyl acetate 70:30); mp 135–137 °C (recrystallized from ethyl acetate to give beige crystals). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.81$ (d, $J = 8.1$ Hz, 1H), 7.61 (t, $J = 8.1$ Hz, 1H), 7.43 (d, $J = 8.1$ Hz, 1H), 7.38–7.26 (m, 4H), 7.17–7.15 (m, 1H), 3.77 (s, 3H), 2.33 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 161.3$, 142.9, 139.2, 138.7, 134.1, 131.1, 130.5, 130.3, 129.5, 128.4, 127.7, 125.8, 122.2, 121.3, 114.3, 29.9, 16.9; IR (film): $\nu = 1634$, 1594, 1566, 1460, 1313 cm^{-1}; HR-MS (ES$^+$): $m/z = 306.0661$, calculated for $C_{17}H_{14}NONa^{35}Cl$ $[M+Na]^+$: 306.0662.

***4-(Cyclopropylmethyl)-1-methyl-3-phenylquinolin-2(1H)-one* (3v):** Following the general procedure for decarboxylative coupling, a mixture of 4-(cyclopropylmethyl)-1-methyl-2-oxo-1,2-dihydroquinoline-3-carboxylic acid **1g** (128.5 mg, 0.5 mmol) and iodobenzene (204 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 90:10 to 80:20) to afford the desired product **3v** as an orange solid; yield: 84 mg, 0.29 mmol (58%); R_f 0.33 (cyclohexane/ethyl acetate 70:30); mp 122–124 °C (precipitated from ethyl acetate/hexane to give an orange powder). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.96$ (d, $J = 8.1$ Hz, 1H), 7.59 (t, $J = 8.4$ Hz, 1H), 7.45–7.24 (m, 7H), 3.77 (s, 3H), 2.69 (d, $J = 6.3$ Hz, 2H), 0.98–0.87 (m, 1H), 0.40–0.36 (m, 2H), −0.01–0.03 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 162.2$, 146.4, 139.8, 137.0, 132.7, 130.3 (2C), 130.2, 128.3 (2C), 127.6, 126.5, 122.0, 120.9, 114.6, 33.8, 30.0, 11.2, 5.6 (2C); IR (film): $\nu = 1630$, 1589, 1458, 1312 cm^{-1}; HR-MS (ES$^+$): $m/z = 312.1355$, calculated for $C_{20}H_{19}NONa$ $[M+Na]^+$: 312.1359.

***4-Methoxy-3-(4-methoxyphenyl)-1-methylquinolin-2(1H)-one* (3w):** Following the general procedure for decarboxylative coupling, a mixture of 4-methoxy-1-methyl-2-oxo-1,2-dihydroquinoline-3-carboxylic acid **1h** (116.5 mg, 0.5 mmol) and 1-iodo-4-methoxybenzene (234 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 85:15 to 70:30) to afford the desired product **3w** as a beige solid; yield: 73 mg, 0.25 mmol (50%); R_f 0.25 (cyclohexane/ethyl acetate 70:30); mp 121 °C (recrystallized from ethyl acetate to give beige crystals). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 8.00$ (d, $J = 7.8$ Hz, 1H), 7.59 (t, $J = 8.1$ Hz, 1H), 7.44 (d, $J = 8.7$ Hz, 2H), 7.37 (d, $J = 8.7$ Hz, 1H), 7.27 (t, $J = 7.5$ Hz, 1H), 6.97 (d, $J = 8.7$ Hz, 2H), 3.86 (s, 3H), 3.75 (s, 3H), 3.52 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 163.6$, 160.2, 159.1, 139.2, 132.0, 130.8, 125.6, 124.1, 121.9, 119.0, 118.3, 113.9, 113.6, 60.7, 55.3, 29.9, IR (film): $\nu = 1633$, 1607, 1512, 1462, 1352, 1307, 1290, 1247, 1178, 1105 cm^{-1}; HR-MS (ES$^+$): $m/z = 318.1098$, calculated for $C_{18}H_{17}NO_3Na$ $[M+Na]^+$: 318.1106.

The side product [the protodecarboxylated compound *4-methoxy-1-methylquinolin-2(1H)-one*] (**3w′**) was also isolated as beige solid; yield: 42 mg, 0.22 mmol (44%); R_f 0.18 (cyclohexane/ethyl acetate 50:50); mp 66 °C (recrystallized from ethyl acetate to give beige crystals). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.97$ (d, $J = 8.1$ Hz, 1H), 7.59 (t, $J = 7.2$ Hz, 1H), 7.35 (d, $J = 8.7$ Hz, 1H), 7.24 (t, $J = 7.8$ Hz, 1H), 6.11 (s, 1H), 3.95 (s, 3H), 3.68 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 164.0$, 163.0, 139.8, 131.5, 123.6, 122.0, 116.7, 114.3, 96.4, 56.0, 29.3, IR (film): $\nu = 1635$, 1587, 1391, 1234 cm^{-1}; HR-MS (ES$^+$): $m/z = 190.0859$, calculated for $C_{11}H_{12}NO_2$ $[M+H]^+$: 190.0863.

***Ethyl 3-(4-methoxy-1-methyl-2-oxo-1,2-dihydroquinolin-3-yl)benzoate* (3x):** Following the general procedure for decarboxylative coupling, a mixture of 4-methoxy-1-methyl-2-oxo-1,2-dihydroquinoline-3-carboxylic acid **1h** (116.5 mg, 0.5 mmol) and ethyl 3-iodobenzoate (275 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 80:20 to 70:30) to afford the desired product **3x** as a beige solid; yield: 94 mg, 0.28 mmol (56%); R_f 0.27 (cyclohexane/ethyl acetate 70:30); mp 86 °C (precipitated from ethyl acetate/cyclohexane to give a beige powder). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 8.18$ (s, 1H), 8.06 (d, $J = 7.8$ Hz, 1H), 8.00 (d, $J = 7.8$ Hz, 1H), 7.70 (d, $J = 7.5$ Hz, 1H), 7.62 (t, $J = 7.8$ Hz, 1H), 7.52 (t, $J = 7.5$ Hz, 1H), 7.40 (d, $J = 8.1$ Hz, 1H), 7.28 (t, $J = 7.5$ Hz, 1H), 4.38 (q, $J = 7.2$ Hz, 2H), 3.75 (s, 3H), 3.51 (s, 3H), 1.39 (t, $J = 7.2$ Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 166.7$, 163.3, 160.9, 139.6, 135.4, 134.0, 132.0, 131.3, 130.6, 129.1, 128.2, 124.4, 122.2, 118.7, 118.2, 114.1, 61.2, 61.1, 30.0, 14.5, IR (film) ν 1716, 1637, 1593, 1463, 1354, 1292, 1263, 1225, 1107, HR-MS (ES$^+$): $m/z = 360.1218$, calculated for $C_{20}H_{19}NO_4Na$ $[M+Na]^+$: 360.1212.

***3-(3-Chlorophenyl)-4,6,7-trimethoxy-1-methylquinolin-2(1H)-one* (3y):** Following the general procedure for decarboxylative coupling, a mixture of 4,6,7-trimethoxy-1-methyl-2-oxo-1,2-dihydroquinoline-3-carboxylic acid **1i** (146.5 mg, 0.5 mmol) and 1-chloro-3-iodobenzene (238.5 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 80:20 to 70:30) to afford the desired product **3y** as a beige solid; yield: 59 mg, 0.16 mmol (33%); R_f 0.10 (cyclohexane/ethyl acetate 70:30); mp 165–166 °C (recrystallized from ethyl acetate to give beige crystals); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.51$ (s, 1H), 7.39–7.33 (m, 4H), 6.81 (s, 1H), 4.04 (s, 3H), 3.97 (s, 3H), 3.74 (s, 3H), 3.52 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 163.1$, 160.7, 152.8, 145.4, 135.9, 135.3, 134.0, 131.1, 129.4, 129.3, 127.8, 116.0, 111.0, 105.0, 97.2, 61.1, 56.4 (2C), 30.3; IR (film): $\nu = 2936$, 1623, 1517, 1250, 1206, 1004 cm^{-1}; HR-MS (ES$^+$): $m/z = 382.0817$, calculated for $C_{19}H_{18}NO_4Na^{35}Cl$ $[M+Na]^+$: 382.0822.

***3-(4-Methoxyphenyl)-4-phenyl-2H-chromen-2-one* (5a):**[20] Following the general procedure for decarboxylative coupling, a mixture of 2-oxo-4-phenyl-2*H*-chromene-3-carboxylic acid **4a** (133 mg, 0.5 mmol) and 1-iodo-4-methoxybenzene (234 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 90:10 to 80:20) to afford the desired product **5a** as a yellow solid; yield: 123 mg, 0.37 mmol (75%); R_f 0.57 (cyclohexane/ethyl acetate 70:30); mp 175 °C (recrystallized from ethyl acetate to give yellow crystals). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 7.55$–7.49 (m, 1H), 7.42 (d, $J = 8.1$ Hz, 1H), 7.35–7.31 (m, 3H), 7.22–7.12 (m, 4H), 7.06 (d, $J = 8.7$ Hz, 2H), 6.72 (d, $J = 8.7$ Hz, 2H), 3.74 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 161.7$, 159.0, 153.2, 151.2, 134.9, 132.0 (2C), 131.3, 129.5 (2C), 128.5 (2C), 128.4, 127.8, 126.7, 126.2, 124.2, 120.8, 116.8, 113.4 (2C), 55.3; IR (film): $\nu = 1713$, 1609, 1512, 1298, 1249 $\ll$ cm^{-1}.

***3-(4-Chlorophenyl)-7-methoxy-4-(4-methoxyphenyl)-2H-chromen-2-one* (5b):** Following the general procedure for decarboxylative coupling, a mixture of 7-methoxy-4-(4-methoxyphenyl)-2-oxo-2*H*-chromene-3-carboxylic acid **4b** (163 mg, 0.5 mmol) and 1-chloro-4-iodobenzene (238.5 mg, 1.0 mmol) was heated for 1 h. The residue was purified by

flash chromatography over silica gel (cyclohexane/ethyl acetate 90:10) to afford the desired product **5b** as a pale yellow solid; yield: 173 mg, 0.44 mmol (88%); R_f 0.59 (cyclohexane/ethyl acetate 70 :30); mp 173–175 °C (recrystallized from ethyl acetate to give white crystals); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.19–7.15 (m, 3H), 7.05 (d, J = 8.4 Hz, 2H), 7.01 (d, J = 8.4 Hz, 2H), 6.91 (d, J = 2.4 Hz, 1H), 6.84 (d, J = 8.7 Hz, 2H), 6.76 (dd, J = 2.4–8.7 Hz, 1H), 3.89 (s, 3H), 3.81 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 162.8, 161.6, 159.7, 155.1, 152.2, 133.4, 133.0, 132.3 (2C), 130.9, 129.1, 128.2, 126.7, 122.6, 114.2, 114.0 (2C), 112.4, 100.8, 55.9, 55.4; IR (film): ν = 1714, 1615, 1548, 1294, 1266, 1032 cm^{-1}; HR-MS (ES$^+$): m/z = 415.0693, calculated for $C_{23}H_{17}O_4Na^{35}Cl$ [M + Na]$^+$: 415.0708.

***3-(4-Methoxyphenyl)-4-propyl-2H-chromen-2-one* (5c):** Following the general procedure for decarboxylative coupling, a mixture of 2-oxo-4-propyl-2*H*-chromene-3-carboxylic acid **4c** (116 mg, 0.5 mmol) and 1-iodo-4-methoxybenzene (234 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 90:10 to 80:20) to afford the desired product **5c** as a pale yellow solid; yield: 94 mg, 0.32 mmol (64%); R_f 0.55 (cyclohexane/ethyl acetate 70:30); mp 153 °C (recrystallized from ethyl acetate to give white crystals). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.66 (d, J = 7.8 Hz, 1H), 7.52 (t, J = 8.1 Hz, 1H), 7.37 (d, J = 8.4 Hz, 1H), 7.31 (t, J = 7.8 Hz, 1H), 7.21 (d, J = 8.7 Hz, 2H), 6.99 (d, J = 8.7 Hz, 2H), 3.86 (s, 3H), 2.68–2.63 (m, 2H), 1.67–1.55 (m, 2H), 0.91 (t, J = 7.2 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 161.6, 159.5, 153.3, 152.0, 131.2, 131.0 (2C), 127.0, 126.9, 125.3, 124.3, 119.8, 117.3, 114.1 (2C), 55.4, 31.7, 23.3, 14.5, IR (film): ν = 2963, 1713, 1601, 1512, 1247 cm^{-1}; HR-MS (ES$^+$): m/z = 317.1128, calculated for $C_{19}H_{18}O_3Na$ [M + Na]$^+$: 317.1148.

***7-Chloro-4-methoxy-1-methyl-3-phenylquinolin-2(1H)-one* (6a):** Following the general procedure for decarboxylative coupling, a mixture of 7-chloro-4-methoxy-1-methyl-2-oxo-1,2-dihydroquinoline-3-carboxylic acid **1j** (133.75 mg, 0.5 mmol) and iodobenzene (204 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 80:20) to afford the desired product **6a** as a beige solid; yield: 72.5 mg, 0.24 mmol (48%); R_f 0.50 (cyclohexane/ethyl acetate 70:30), mp 127–128 °C (recrystallized from hexane/dichloromethane to give a white solid). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.93 (d, J = 8.7 Hz, 1H), 7.48–7.36 (m, 6H), 7.23 (dd, J = 1.8–8.4 Hz, 1H), 3.71 (s, 3H), 3.48 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 163.5, 159.9, 140.1, 137.1, 133.4, 130.8 (2C), 128.2 (2C), 128.0, 125.6, 122.3, 119.0, 116.9, 114.0, 61.0, 30.0; IR (film): ν = 2852, 1640, 1613, 1588, 1354, 1311, 1102 cm^{-1}; HR-MS (ES$^+$): m/z = 322.0603, calculated for $C_{17}H_{14}NO_2Na^{35}Cl$ [M + Na]$^+$: 322.0611.

***7-Chloro-4-methoxy-3-(3-(4-methoxybenzyl)phenyl)-1-methylquinolin-2(1H)-one* (6b):** Following the general procedure for decarboxylative coupling, a mixture of 7-chloro-4-methoxy-1-methyl-2-oxo-1,2-dihydroquinoline-3-carboxylic acid **1j** (125.8 mg, 0.47 mmol) and 1-iodo-3-(4-methoxybenzyl)benzene (324 mg, 1.0 mmol) was heated for 1 h. The residue was purified by flash chromatography over silica gel (cyclohexane/ethyl acetate 80:20 to 70:30) to afford the desired product **6b** as a yellow oil; yield: 111 mg, 0.26 mmol (56%); R_f 0.43 (cyclohexane/ethyl acetate 70:30). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.90 (d, J = 8.4 Hz, 1H), 7.38–7.31 (m, 4H), 7.21 (dd, J = 1.8–8.7 Hz, 1H), 7.19–7.15 (m, 1H), 7.12 (d, J = 8.7 Hz, 2H), 6.82 (d, J = 8.7 Hz, 2H), 3.98 (s, 2H), 3.78 (s, 3H), 3.69 (s, 3H), 3.45 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ = 163.5, 159.8, 158.0, 141.4 (2C), 140.1, 137.1, 133.4, 131.3, 129.9 (2C), 128.6, 128.5, 128.3, 125.6, 122.3, 119.0, 116.9, 113.9 (3C), 60.9, 55.3, 41.1, 30.0; IR (film): ν = 1641, 1614, 1589, 1511, 1246; HR-MS (ES$^+$): m/z = 442.1163, calculated for $C_{25}H_{22}NO_3Na^{35}Cl$ [M + Na]$^+$: 442.1180.

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