Ruthenium-Catalyzed C-H Arylation of Diverse Aryl Carboxylic Acids with Aryl- and Heteroaryl Halides

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Supporting Information

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I. General Informations

Reagents

Metals

[Ru(p-cymene)Cl₂]₂ (Alfa Aesar), [IrCp*Cl₂]₂ (Alfa Aesar) CoBr₂ (Aldrich), CrCl₃ (Strem), Cu(OAc)₂ (Aldrich), RuCl₃ hydrate (Pressure Chemical), were used as received and stored on the bench. (p-cymene)Ruκ₂-O,C-napthenoate(py) was prepared according to the literature procedure.¹

Ligand

4-4’-di-tert-butyl-2,2’-bipyridine (Aldrich) and PCy₃ (Aldrich) was used as received. Other ligands tested were from commercial suppliers and used as received.

Solvents

NMP, anhydrous, 99.5% (Sigma-Aldrich) was stored in a nitrogen-filled glove box.

Other Reagents

Dodecane (Aldrich), K₂CO₃ (Combi-blocks), Cs₂CO₃ (Alfa Aesar), MeI (Aldrich), carboxylic acids and (het)aryl halides (Alfa Aesar, Aldrich, Combi-Blocks, etc.) were used as received.

Methods

NMR Spectroscopy

¹¹H nuclear magnetic resonance (NMR) spectroscopy chemical shifts are reported in ppm and referenced to TMS (tetramethylsilane) in CDCl₃ (δ = 0 ppm) or the residual solvent peak for CDCl₃ (δ = 7.26 ppm). For ¹³C NMR and ¹⁹F NMR chemical shifts, the residual solvent peak (CDCl₃, δ = 77.00 ppm) and the external standard, a,a,a-trifluorotoluene (δ = 0 ppm) were used as references. NMR spectra were recorded on Avance Bruker NMR spectrometers operating at either 400.13 MHz or 500.13 MHz and data analysis was performed using the iNMR software package (www.inmr.net). Chemical shifts are reported in parts per million (ppm), multiplicities are indicated by s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet) and br (broad). Coupling constants (J) are reported in Hertz.

Gas Chromatography

GC analyses were performed on an Agilent 7890A GC equipped with dual DB-5 columns (20 m × 180 μm × 0.18 μm), dual FID detectors, and hydrogen as the carrier gas. A sample volume of 1 μL was injected at a temperature of 300 °C and a 100:1 split ratio. The initial inlet pressure was 20.3 psi but varied as the column flow was held constant at 1.8 mL/min for the duration of the run. The initial oven temperature of 50 °C was held for 0.46 min followed by a temperature ramp of 65 °C/min up to 300 °C.

¹ Warratz, S.; Kornhaaß, C.; Cajaraville, A.; Niepötter, B.; Stalke, D.; Ackermann, L., Angew. Chem. Int. Ed. 2015, 54, 5513-5517
The temperature was held at 300 °C for 3 min. The total run time was ~7.3 min and the FID temperature was 325 °C.

**GC/MS Analysis**

GC/MS analyses were performed on a Shimadzu GCMS-QP2010 equipped with an RTX-XLB column (30 m × 0.25 mm × 0.28 µm) with a quadrupole mass analyzer using helium as the carrier gas. The analysis method used in all cases was 5 µL injection of sample, an injection temp of 225 °C, and a 25:1 split ratio. The initial inlet pressure was 7.8 psi, but varied as the column flow was held constant at 1.0 mL/min for the duration of the run. The interface temperature was held at 250 °C, and the ion source (EI+, 30 eV) was held at 250 °C. The initial oven temperature was held at 50 °C for 2 min with the detector off, followed by a temperature ramp, with the detector on, to 280 °C at 40 °C/min. The temperature was held at 280 °C for 3 min. Total run time was 11.75 min.

**Low Resolution Mass Spectrometry (LRMS) Analysis**

LRMS analyses were performed on a Shimadzu LCMS-2010A equipped with an ESI or APCI probe with a quadrupole mass analyzer. Direct injection analysis was employed in all cases with 5 µL of sample solution in methanol. The ion source (electron spray ionization, ESI) was held at 250 °C or 400 °C when atmospheric-pressure chemical ionization (APCI) was used, sample flow rate at 1 mL/min.

**Infrared Spectroscopy**

Infrared (IR) spectra were recorded on a Shimadzu IRAffinity-1 Fourier Transform Infrared Spectrophotometer and are reported in wavenumbers (cm⁻¹).

**Chromatography**

Chromatography was performed on silica gel (EMD, silica gel 60, particle size 0.040-0.063 mm) using standard flash techniques or on 40 g HP Silica column (catalog 69-2203-347) using a Teledyne Isco Rf-200 (detection at 210 nm). Products were visualized by UV, iodine stain, ceric ammonium molybdate stain, or KMnO₄ stain.
II. Coupling of (Hetero)Aromatic Acids with (Hetero)Aryl Halides

Optimization of the Coupling of 2-Methylbenzoic Acid with Aryl Halides

Table S1. Effect of Aryl Electrophile and Additives on C-H Arylation Reaction.

| entry | 2       | additive       | yield of 3a (%) |
|-------|---------|----------------|-----------------|
| 1     | X = Cl  | Zn (50 mol %)  | n.d.            |
| 2     | X = Br  | Zn (50 mol %)  | trace           |
| 3     | X = I   | Zn (50 mol %)  | 32              |
| 4     | X = OTf | Zn (50 mol %)  | 57              |
| 5b    | X = I   | Zn (50 mol %)  | n.d.            |
| 6c    | X = I   | Zn (50 mol %)  | trace           |
| 7d    | X = I   | Zn (50 mol %)  | 20              |
| 8c    | X = I   | Zn (50 mol %)  | 39              |
| 8     | X = I   | -              | 10              |
| 9f    | X = I   | Zn (50 mol %)  | n.d.            |
| 10g   | X = I   | Zn (50 mol %)  | 35              |

*a Reaction conditions: 1a (0.25 mmol), 2 (0.375 mmol), [Ru(p-cymene)Cl2]2 4 mol %, NiBr2 dme (5 mol %), dtbbpy (5 mol %), K2CO3 (1 equiv), 80 °C, 24 h. GC yield after esterification with K2CO3/MeI, with n-dodecane as internal standard. b K2CO3 (2 equiv) as base. c K2CO3 (1 equiv), and KOAc (1 equiv) as base. d 60 °C. e 100 °C. f without Ligand. g without Ni-catalyst.
**Table S2. Ligand Effects in the Ru-Catalyzed C-H Arylation of \( \alpha \)-Toluic Acid.**

![Chemical structures](image)

| Entry | [Ru] (\%) | ligand (\%) | solvent | yield of 3a (\%) |
|-------|-----------|-------------|---------|-----------------|
| 1     | 4         | L1, 4 mol %| NMP     | 48              |
| 2     | 4         | L1, 8 mol %|         | 46              |
| 3     | 4         | L1, 4 mol %| toluene | n.d.            |
| 4     | 4         | L1, 4 mol %| dioxane | trace           |
| 5     | 4         | L1, 4 mol %| DMAc    | 41              |
| 6     | 4         | L1, 4 mol %| DMF     | 40              |
| 7     | 4         | L1, 4 mol %| H2O     | n.d.            |
| 8     | 4         | L1, 4 mol %| i-PrOH  | n.d.            |
| 9     | 4         | L2, 4 mol %| NMP     | n.d.            |
| 10    | 4         | L2, 4 mol %|         | 58              |
| 11    | 4         | L4, 4 mol %|         | 67              |
| 12b   | 4         | L4, 4 mol %|         | n.d.            |
| 13c   | "         | L4, 4 mol %|         | 54              |
| 14d   | "         | L4, 4 mol %|         | 23              |
| 15    | "         | L4, 4 mol %|         | trace           |
| 16    | "         | L4, 4 mol %|         | n.d.            |
| 17    | "         | L4, 4 mol %|         | n.d.            |
| 18    | "         | L4, 8 mol %|         | 12              |
| 19    | "         | L4, 8 mol %|         | 9               |
| 20    | "         | L10, 8 mol %| "      | 91 (94)         |
| 21    | 2         | L10, 4 mol %|         | 83              |
| 22    | 1         | L10, 2 mol %|         | 54              |
| 23    | "         | L11, 8 mol %|         | 51              |
| 24    | "         | L11, 8 mol %|         | 28              |
| 25    | 4         | L14, 8 mol %|         | 9               |
| 26    | 4         | L14, 4 mol %|         | trace           |
| 27    | 4         | L14, 4 mol %|         | 44              |
| 28    | "         | L14, 4 mol %|         | trace           |
| 29    | "         | L14, 4 mol %|         | trace           |
| 30    | "         | L14, 4 mol %|         | n.d.            |

*Reaction conditions: 1a (0.25 mmol), 2 (0.375 mmol), [Ru(\(p\)-cymene)Cl2]2 1-4 mol %, ligand (4-8 mol %), K2CO3 (1 equiv), 100 °C, 24 h. GC yield after esterification with K2CO3/MeI, with \( n \)-dodecane as internal standard. b Ag2CO3 (1 equiv) as base. c Cs2CO3 (1 equiv) as base. d Na2CO3 (1 equiv) as base.
Table S3. C-H Arylation with Alternative Metals and PCy3.

| entry | cat. M           | yield of 3a (%) |
|-------|------------------|-----------------|
| 1     | CoBr₂            | n.d.            |
| 2     | Cp*CoMe₂         | n.d.            |
| 3     | CrCl₃            | n.d.            |
| 4     | RuCl₂·3H₂O       | 68              |
| 5     | Cu(OAc)₂         | n.d.            |
| 6     | [IrCp*Cl₂]₂      | 11              |
| 7     | [IrCp*Cl₂]₂      | 11              |
| 8     | [IrCp*Cl₂]₂      | 12              |

* Reaction conditions: 1a (0.25 mmol), 2a (0.375 mmol), cat. M (4 mol %), PCy₃ (8 mol %), K₂CO₃ (1 equiv), 160 °C, 24 h. GC yield after esterification with K₂CO₃/MeI, with n-dodecane as internal standard.  

Additional Control and Mechanistic Experiments

*Amide vs carboxylate as directing group*

```
O
\[ \text{N-Bu} \quad \text{Me} \quad \text{O} \]

0.25 mmol 0.25 mmol 1.5 equiv

1) [Ru(p-cym)Cl₂]₂ 4 mol % PCy₃ 8 mol %, K₂CO₃ 1 equiv NMP 1 mL, 100 °C, 24 h

[Me CO₂Me]

91% NMR yield

no detected

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*Ketone vs carboxylate as directing group*

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O
\[ \text{Me} \quad \text{O} \]

0.25 mmol 0.25 mmol 1.5 equiv

1) [Ru(p-cym)Cl₂]₂ 4 mol % PCy₃ 8 mol %, K₂CO₃ 1 equiv NMP 1 mL, 100 °C, 24 h

[Me CO₂Me]

96% NMR yield

trace

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Figure S1. Competition experiments between 2-methylbenzoic acid and N-tert-butylbenzamide and acetophenone. These results demonstrate that carboxylate over-rides both amide and ketone directing groups under these conditions.
**Figure S2.** Radical trap experiments. When 1 equiv of TEMPO (~0.25 M) was added to the reaction under standard conditions, nearly quantitative amounts of the starting material (77% uncorrected GC yield vs dodecane as internal standard) was recovered. When the 1 equiv of BHT (~0.25 M) was added into the reaction, nearly all the carboxylic acid was transformed into the desired product (86% uncorrected GC yield vs dodecane as internal standard). These results are inconclusive for the involvement of radicals. While the TEMPO result is consistent with a radical intermediate, TEMPO can also react directly with transition metals. BHT did not affect the reaction, but this cannot rule out radicals that simply react faster in the desired pathway.

**Figure S3.** Stoichiometric Reaction. When \((\text{p-cymeneene})\text{Ru(κ}^2\text{O,C-napthenoate)(py)}\text{Cl (8)}\) and PhI (2a) were stirred in NMP (0.2 mL) at 100 °C for 30 mins, the desired product 4ha was formed only when PCy₃ was present. (32% yield vs. none detected). Without the phoshine ligand, only the methyl ester of starting material could be found.

**Figure S4.** Kinetic Competency of Cyclometalated Complex 8. When complex 8 was used as a pre-catalyst, the standard reaction was complete in 0.5 h. This is considerably faster than reactions catalyzed by \([(\text{p-cymene})\text{RuCl}_2]\)₂ either with or without added pyridine. Note that the reaction with added pyridine was considerably slower to form product, consistent with the longer times required for heteroaryl halides.

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2 See, for example, the Cu/TEMPO oxidation of alcohols: Hoover, J. M.; Ryland, B. L.; Stahl, S. S. *J. Am. Chem. Soc.* 2013, 135, 2357.
General Procedure for the Coupling of 2-Methylbenzoic Acid and Aryl Halides.

\[
\begin{align*}
\text{Me} & \quad O \quad H \quad X \quad \text{R} \quad 1 \quad \text{Me} \\
\text{OH} & \quad \text{R} \quad 1 \\
\text{Me} & \quad O \quad H \quad \text{R} \quad 1 \quad \text{Me} \\
\text{OMe} & \quad \text{Me} \\
\end{align*}
\]

On the bench, an oven-dried 1-dram vial fitted with a Teflon-coated stir-bar was charged with 
\([\text{Ru}(p\text{-cymene})\text{Cl}_2]_2\) (6.2 mg, 0.01 mmol, 4 mol %), 2-methylbenzoic acid (35 mg, 0.25 mmol, 1.0 equiv), and \(\text{K}_2\text{CO}_3\) (34.5 mg, 0.25 mmol, 1.0 equiv). The vial was moved into a nitrogen filled glove box and subsequently charged with \(\text{PCy}_3\) (5.6 mg, 0.02 mmol, 8 mol %), dodecane (as an internal standard, 20.0 µL), aryl halide (0.375 mmol, 1.50 equiv), and \(\text{NMP}\) (1.00 mL). The vial was capped with a screw cap fitted with a PTFE-faced silicone septum, removed from the glove box, and heated in a reaction block set to 100 °C on the benchtop with stirring at 1195 rpm for 24 h.

After stirring for 24 hours, the reaction was removed from the plate and charged with \(\text{MeI}\) (0.1 mL, 1.6 mmol, 6.4 equiv), another 2-3 equiv of \(\text{K}_2\text{CO}_3\) (69-138 mg), and \(\text{MeCN}\) (0.5 mL). The resulting mixture was stirred for 2 hours at 60 °C.

**GC Analysis.**

After the esterification reaction was complete, the reaction vial was vented to an oil bubbler before a 25 µL aliquot of the reaction mixture was removed with a 50 µL gas-tight syringe. The aliquot was diluted with diethyl ether (1.5 mL) and filtered through a short silica pad (about 1.5 cm) in a pipette packed with glass wool. The filtrate was analyzed by gas chromatography and percent yield was calculated versus dodecane as the internal standard.

**Isolation and Purification**

When the reaction was judged complete, the reaction mixture was filtered through a short plug of silica gel (1.5 cm wide × 2 cm high) to remove metal salts and the pad was washed with diethyl ether (75 mL). The filtrate was poured into a separatory funnel and partitioned with deionized water (30 mL). The aqueous layer was then extracted with diethyl ether (3 × 30 mL). The combined organic layers were dried over MgSO₄, filtered, and the filtrate was concentrated under reduced pressure. The resulting residue was purified by column chromatography on silica gel to afford the pure product.
Methyl 3-methylbiphenyl-2-carboxylate (3a) [CAS: 941320-77-0]\(^3\)

![Chemical Structure](attachment:image.png)

Compound 3a was prepared following the general procedure, starting from 2-methylbenzoic acid (35 mg, 0.25 mmol) and phenyl iodide (76.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 3a was obtained as colorless liquid (53.1 mg, 94% isolated yield). H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.36–7.32 (m, 4H), 7.30 – 7.27 (m, 2H), 7.19 – 7.16 (m, 2H), 3.53 (s, 3H), 2.36 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 170.2, 140.9, 140.1, 135.4, 133.1, 129.4, 129.1, 128.2, 128.2, 127.3, 127.2, 51.8, 19.7. MS (APCI+), m/z: 226.85 [M+H\(^+\)]. IR: \(\tilde{\nu}\) = 2947, 2160, 1724, 1435, 1265, 1123, 1065, 756, 698.

Methyl 4’-chloro-3-methylbiphenyl-2-carboxylate (3b) [CAS: 1809272-61-4]\(^3\)

![Chemical Structure](attachment:image.png)

Compound 3b was prepared following the general procedure, starting from 2-methylbenzoic acid (35 mg, 0.25 mmol) and 1-chloro-4-iodobenzene (89.3 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 3a was obtained as colorless liquid (59.2 mg, 91% isolated yield). H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.36 (t, \(J = 8.0\ Hz\), 3H), 7.30 (d, \(J = 8.4\ Hz\), 2H), 7.23 (d, \(J = 7.6\ Hz\), 1H), 7.18 (d, \(J = 7.6\ Hz\), 1H), 3.62 (s, 3H), 2.40 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): 170.0, 139.3, 138.8, 135.6, 133.5, 133.0, 129.5, 129.4, 128.4, 127.0, 51.9, 19.7. GCMS, m/z (% relative intensity, ion): 262[M+2\(^+\)] (14), 260[M\(^+\)] (44), 231 (21), 229 (67), 193 (36), 166 (64), 165 (100), 152 (9). IR: \(\tilde{\nu}\) = 2947, 2160, 1975, 1724, 1458, 1265, 1123, 1084, 1065, 787.

Methyl 4'-methoxy-3-methylbiphenyl-2-carboxylate (3c) [CAS: 1097018-19-3]\(^3\)

![Chemical Structure](attachment:image.png)

Compound 3c was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 1-iodo-4-methoxybenzene (87.8 mg, 0.375 mmol). After

\(^3\) Huang, L.; Hackenberger, D.; Gooßen, L. J., *Angew. Chem. Int. Ed.* 2015, 54, 12607-12611.
puriﬁcation by column chromatography (ethyl acetate / hexane = 10:1), 3e was obtained as beige liquid (52.5 mg, 82% isolated yield). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.33 (dd, $J = 16$ Hz, 8.0 Hz, 3H), 7.21 – 7.18 (m, 2H), 6.93 (d, $J = 12$ Hz, 2H), 3.84 (s, 3H), 3.63 (s, 3H), 2.4 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ = 170.5, 159.0, 139.6, 135.2, 133.2, 133.1, 129.3, 128.7, 127.1, 113.7, 55.2, 51.8, 19.6. GCMS, m/z (% relative intensity, ion): 256[M$^+$] (100), 225 (84), 209 (27), 182 (47), 165 (44), 153 (66), 139 (27), 115 (17), 76 (8). IR: $\tilde{\nu}$ = 2928, 2160, 1724, 1609, 1512, 1246, 1180, 1088, 787.

**Dimethyl 3-methylbiphenyl-2,4'-dicarboxylate (3d) [CAS: 1809272-59-0]**

![Dimethyl 3-methylbiphenyl-2,4'-dicarboxylate (3d)](image)

Compound 3d was prepared following procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol), methyl-4-iodobenzoate (98.3 mg, 0.375 mmol). After puriﬁcation by column chromatography (ethyl acetate / hexane = 10:1), 3d was obtained as white solid (62.5 mg, 88% isolated yield). m.p. = 71 – 75 °C. $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 8.06 (d, $J = 8.0$ Hz, 2H), 7.43 (d, $J = 8.0$ Hz, 2H), 7.37 (t, $J = 8.0$ Hz, 1H), 7.23 (dd, $J = 15.2$ Hz, 8.0 Hz, 2H), 3.93 (s, 3H), 3.57 (s, 3H), 2.40 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 169.8, 166.8, 145.6, 139.1, 135.8, 132.9, 129.8, 129.5, 129.0, 128.2, 127.0, 52.1, 51.9, 19.7. GCMS, m/z (% relative intensity, ion): 284[M$^+$] (55), 253 (52), 209 (30), 194 (23), 181 (13), 165 (100), 152 (13), 139 (12), 111 (9), 59 (15). IR: $\tilde{\nu}$ = 2928, 2160, 1975, 1705, 1435, 1261, 1180, 1115, 1065, 772.

**Methyl 4'-acetyl-3-methylbiphenyl-2-carboxylate (3e) [CAS: 1809272-58-9]**

![Methyl 4'-acetyl-3-methylbiphenyl-2-carboxylate (3e)](image)

Compound 3e was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 1-(4-iodophenyl)ethanone (92.3 mg, 0.375 mmol). After puriﬁcation by column chromatography (ethyl acetate / hexane = 10:1), 3e was obtained as brown oil (52.3 mg, 78% isolated yield). m.p. = 124 – 127 °C. $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.98 (d, $J = 8.0$ Hz, 2H), 7.45 (d, $J = 8.0$ Hz, 2H), 7.37 (t, $J = 8.0$ Hz, 1H), 7.25 (d, $J = 8.0$ Hz, 2H), 7.20 (d, $J = 8.0$ Hz, 1H), 3.59 (s, 3H), 2.62 (s, 3H), 2.40 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 197.7, 169.8, 145.7, 139.0, 135.9, 135.8, 132.9, 129.8, 129.5, 128.4, 128.3, 127.0, 124.6, 1180, 1088, 787.
51.9, 26.6, 19.7. GCMS, m/z (% relative intensity, ion): 268[M⁺] (46), 253 (100), 195 (38), 165 (62), 152 (16), 139 (11), 115 (8). IR: ν = 2924, 2160, 1717, 1678, 1269, 1180, 1119, 795.

**Methyl 3-methyl-3’-(trifluoromethyl)biphenyl-2-carboxylate (3f)**

![Methyl 3-methyl-3’-(trifluoromethyl)biphenyl-2-carboxylate (3f)](image)

Compound 3f was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 1-iodo-3-(trifluoromethyl)benzene (102 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 3f was obtained as colorless liquid (61.7 mg, 84% isolated). $^1$H NMR (400 MHz, CDCl$_3$): δ 7.65 (s, 1H), 7.62 (d, $J$=7.6 Hz, 1H), 7.57 - 7.50 (m, 2H), 7.39 (t, $J$= 7.6 Hz, 1H), 7.27 (d, $J$= 7.6 Hz, 1H), 7.22 (d, $J$= 7.6 Hz, 1H), 3.62 (s, 3H), 2.42 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 169.8, 141.6, 138.5, 135.8, 133.2, 131.6, 130.7 (q, $J$= 25.6 Hz), 129.8, 129.6, 128.8, 127.1, 125.0 (unresolved m), 124.1 (unresolved m), 124.0 (q, $J$= 216.4 Hz), 51.8, 19.7. $^{19}$F NMR (376 MHz, CDCl$_3$): δ 0.22 (s, 3F). GCMS, m/z (% relative intensity, ion): 294[M⁺] (52), 275 (8), 263 (100), 215 (27), 165 (87), 139 (4), 107 (5). IR: ν = 2928, 2160, 1728, 1435, 1335, 1265, 1165, 1119, 1069, 783, 702.

**3’,5’-Dimethoxy-3-methylbiphenyl-2-carboxylic acid (3g)**

![3’,5’-Dimethoxy-3-methylbiphenyl-2-carboxylic acid (3g)](image)

Compound 3g was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 1-bromo-3,5-dimethoxybenzene (81 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 5: 1), 3g was obtained as light yellow solid (44.3 mg, 62% isolated yield). m.p. = 70 - 74 °C. $^1$H NMR (400 MHz, CDCl$_3$): δ 7.35 (t, $J$= 7.6 Hz, 1H), 7.23 (t, $J$= 7.2 Hz, 2H), 6.53 (d, $J$= 2.4 Hz, 2H), 6.45 (m, $J$= 2.0 Hz, 1H), 3.80 (s, 6H), 3.65 (s, 3H), 2.39 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 170.3, 160.6, 142.9, 140.0, 135.4, 133.1, 129.4, 129.3, 127.0, 106.3, 99.9, 55.4, 52.0, 19.6. MS (APCI+), m/z: 286.85 [M+H⁺]. IR: ν = 2928, 2160, 2018, 1975, 1721, 1585, 1416, 1273, 1204, 1153, 1065, 787.

**4’-Pentafluorosulfanyl-3-methylbiphenyl-2-carboxylic acid (3h)**
Compound 3h was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 1-bromo-4-pentafluorosulfanylbenzene (105.8 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 3h was obtained as colorless liquid (62.1 mg, 71% isolated yield). $^1$H NMR (400 MHz, CDCl$_3$): δ 7.78 (d, $J$ = 8.4 Hz, 2H), 7.45 (d, $J$ = 8.4 Hz, 2H), 7.39 (t, $J$ = 8.0 Hz, 1H), 7.28 (d, $J$ = 7.6 Hz, 1H), 7.19 (d, $J$ = 7.6 Hz, 1H), 3.62 (s, 3H), 2.42 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 169.7, 152.8 (unresolved m), 144.4, 138.0, 136.0, 133.0, 130.1. 129.7, 128.5, 127.1, 125.9 (quint, $J$ = 4 Hz), 52.0, 19.7. $^{19}$F NMR (376 MHz, CDCl$_3$): δ 147.3 (quint, $J$ = 151.2 Hz, 1F), 125.9 (d, $J$ = 150.0 Hz, 4F). GCMS, m/z (% relative intensity, ion): 352[M$^+$] (48), 321 (65), 225 (9), 194 (100), 165 (67), 152 (9), 139 (8), 115 (6). IR: $\tilde{\nu}$ = 2927, 2160, 1728, 1439, 1269, 1123, 1069, 821, 787.

Methyl 4'-fluoro-3-methylbiphenyl-2-carboxylate (3i) [CAS: 1809272-60-3]$^3$

Compound 3i was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 1-bromo-4-fluorobenzene (65.3 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 3i was obtained as colorless liquid (45.8 mg, 75% isolated yield). m.p. = 60–64 °C. $^1$H NMR (400 MHz, CDCl$_3$): δ 7.37–7.31 (m, 3H), 7.22 (d, $J$ = 7.2 Hz, 1H), 7.18 (d, $J$ = 7.6 Hz, 1H), 7.10–7.06 (m, 2H), 3.61 (s, 3H), 2.40 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 170.2, 162.3 (d, $J$ = 244.9 Hz), 139.0, 136.9 (d, $J$ = 3.2 Hz), 135.5, 133.2, 129.8 (d, $J$ = 32.4 Hz), 129.3 (d, $J$ = 82 Hz), 127.2, 115.3, 115.1, 51.9, 19.7. $^{19}$F NMR (376 MHz, CDCl$_3$): δ -52.4 (m, 1F). GCMS, m/z (% relative intensity, ion): 244 (100) [M$^+$], 214 (13), 213 (88), 212 (26), 183 (11), 165 (11). IR: $\tilde{\nu}$ = 2924, 2160, 2025, 1735, 1508, 1261, 1119, 1088, 1065, 841, 767.

$^{3',5'}$-Di-tert-butyl-4'-hydroxy-3-methylbiphenyl-2-carboxylic acid (3j)
Compound 3j was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 2,6-di-tert-butyl-4-bromophenol (106.5 mg, 0.375 mmol). After the reaction was complete, the reaction mixture was allowed to cool to rt. The reaction mixture was diluted with ethyl acetate (20 mL) and extracted with aq. NaOH solution (3 × 20 mL). The aq. basic phase was acidified with HCl (pH 1-2) and afterwards extracted with ethyl acetate (3 × 20 mL). The combined organic layers were dried over MgSO₄, filtered, and the volatiles were removed under reduced pressure. The residue was purified by column chromatography (SiO₂, ethyl acetate/hexane = 10:1, 1% formic acid) yielding 3j as a beige solid (57.8 mg, 68% isolated yield). m.p. = 203–210 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.36 (t, J = 8.0 Hz, 1H), 7.28 – 7.26 (m, 3H), 7.19 (d, J = 8.0 Hz, 1H), 5.24 (s, 1H), 2.40 (s, 3H), 1.45 (s, 18H); ¹³C NMR (100 MHz, CDCl₃): δ 176.4, 153.5, 140.8, 135.8, 135.1, 132.3, 131.5, 129.6, 128.4, 127.4, 125.2, 34.4, 30.3, 19.9. MS (APCI+), m/z: 340.95 [M+H⁺]. IR: ν = 2924, 2523, 2160, 1686, 1431, 1300, 1231, 887.

4'-Hydroxy-3-methylbiphenyl-2-carboxylic acid (3k) [CAS: 1261914-93-5]⁴

Compound 3k was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 4-bromophenol (64.5 mg, 0.375 mmol). After the reaction was complete, the reaction mixture was allowed to cool to rt. The reaction mixture was diluted with ethyl acetate (20 mL) and extracted with aq. NaOH solution (3 × 20 mL). The aq. basic phase was acidified with HCl (pH 1-2) and afterwards extracted with ethyl acetate (3 × 20 mL). The combined organic layers were dried over MgSO₄, filtered, and the volatiles were removed under reduced pressure. The residue was purified by column chromatography (SiO₂, ethyl acetate/hexane = 10:1, 1% formic acid) yielding 3k as beige solid (30.2 mg, 53% isolated yield). m.p. = 192–194 °C. ¹H NMR (400 MHz, CD₃CN): δ 7.40 (t, J = 8.0 Hz, 1H), 7.30 – 7.28 (m, 3H), 7.22 (d, J = 8.0 Hz, 1H), 6.89 (d, J = 8.0 Hz, 2H), 2.42 (s, 3H); ¹³C NMR (100 MHz, CD₃CN): δ 170.4, 156.6, 138.9, 134.6, 133.6, 132.2, 129.6, 129.2, 128.5, 127.1, 115.1, 18.8. MS (APCI+), m/z: 228.85 [M+H⁺]. IR: ν = 2928, 2160, 1662, 1516, 1265, 1211, 1169, 829, 775.

⁴ Wu, Z.; Luo, F.; Chen, S.; Li, Z.; Xiang, H.; Zhou, X., Chem. Commun. 2013, 49, 7653-7655.
Methyl 3'-bromo-4'-methoxy-3-methylbiphenyl-2-carboxylate (3l)

\[
\begin{align*}
\text{Compound } 3l & \text{ was prepared following the general procedure, starting from 2-methoxybenzoic acid} \ (35 \text{ mg, } 0.25 \text{ mmol}) \text{ and 2,4-dibromo-1-methoxybenzene} \ (99 \text{ mg, } 0.375 \text{ mmol}). \text{ After purification by column chromatography (ethyl acetate / hexane = 10:1), } 3o & \text{ was obtained as yellow solid} \ (79.3 \text{ mg, 95% isolated yield}). \text{ m.p.} = 84 \text{ – 92 °C. } ^1\text{H NMR} \ (400 \text{ MHz, CDCl}_3): \delta 7.58 \text{ (d, } J = 2.4 \text{ Hz, 1H}), 7.34 \text{ (t, } J = 7.6 \text{ Hz, 1H}), 7.29 - 7.27 \text{ (m, 1H)}, 7.20 \text{ (d, } J = 7.6 \text{ Hz, 1H}), 7.17 \text{ (d, } J = 8.0 \text{ Hz, 1H}), 6.91 \text{ (d, } J = 8.8 \text{ Hz, 1H}), 3.92 \text{ (s, 3H), 3.67 (s, 3H), 3.38 (s, 3H);} \\
\text{13C NMR} \ (100 \text{ MHz, CDCl}_3): \delta 170.2, 155.2, 138.1, 135.5, 134.6, 133.1, 129.4, 129.2, 128.3, 127.1, 111.5, 56.2, 51.9, 19.7. \text{ MS (APCI+), m/z: 334.75 [M+H\text{']}. IR: } \nu = 2947, 1724, 1501, 1439, 1265, 1119, 1096, 1053, 802.
\end{align*}
\]

Methyl 3'-bromo-3,4'-dimethylbiphenyl-2-carboxylate (3m)

\[
\begin{align*}
\text{Compound } 3m & \text{ was prepared following the general procedure, starting from 2-methoxybenzoic acid} \ (35 \text{ mg, } 0.25 \text{ mmol}) \text{ and 2-bromo-4-iodo-1-methylbenzene} \ (111 \text{ mg, } 0.375 \text{ mmol}). \text{ After purification by column chromatography (ethyl acetate / hexane = 10:1), } 3o & \text{ was obtained as light yellow liquid} \ (73.9 \text{ mg, 93% isolated yield}). \text{ } ^1\text{H NMR} \ (400 \text{ MHz, CDCl}_3): \delta 7.58 \text{ (s, 1H), 7.35 (t, } J = 8.0 \text{ Hz, 1H), 7.26 - 7.18 (m, 4H)}, 3.67 \text{ (s, 3H), 2.43 (s, 2H), 2.40 (s, 3H);} \\
\text{13C NMR} \ (100 \text{ MHz, CDCl}_3): \delta 170.1, 155.2, 138.1, 135.5, 134.6, 133.1, 129.4, 129.2, 128.3, 127.1, 124.8, 51.9, 22.6, 19.7. \text{ MS (APCI+), m/z: 318.70 [M+H\text{']}. IR: } \nu = 2947, 1724, 1497, 1435, 1265, 1238, 1119, 1092, 1065, 787.
\end{align*}
\]

Methyl 4'-bromo-3-methylbiphenyl-2-carboxylate (3n) [CAS: 809272-62-5]

\[
\begin{align*}
\text{Compound } 3n & \text{ was prepared following the general procedure, starting from 2-methoxybenzoic acid} \ (35 \text{ mg, } 0.25 \text{ mmol}) \text{ and 2-bromo-4-iodo-1-methylbenzene} \ (111 \text{ mg, } 0.375 \text{ mmol}). \text{ After purification by column chromatography (ethyl acetate / hexane = 10:1), } 3o & \text{ was obtained as light yellow liquid} \ (73.9 \text{ mg, 93% isolated yield}). \text{ } ^1\text{H NMR} \ (400 \text{ MHz, CDCl}_3): \delta 7.58 \text{ (s, 1H), 7.35 (t, } J = 8.0 \text{ Hz, 1H), 7.26 - 7.18 (m, 4H)}, 3.67 \text{ (s, 3H), 2.43 (s, 2H), 2.40 (s, 3H);} \\
\text{13C NMR} \ (100 \text{ MHz, CDCl}_3): \delta 170.1, 140.1, 138.3, 136.9, 135.5, 133.1, 131.9, 130.5, 129.5, 129.4, 127.1, 124.8, 51.9, 22.6, 19.7. \text{ MS (APCI+), m/z: 318.70 [M+H\text{']}. IR: } \nu = 2947, 1724, 1497, 1435, 1265, 1238, 1119, 1092, 1065, 787.
\end{align*}
\]
Compound 3n was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 1-bromo-4-iodobenzene (211.5 mg, 0.75 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 3n and 3n’ were obtained as light yellow solid with about 6:1 ratio (59.3 mg, 78% isolated yield). m.p. = 54–55 °C. 1H NMR (400 MHz, CDCl3): δ 7.43–7.40 (m, 2H), 7.25 (t, J = 7.6 Hz, 1H), 7.15–7.12 (m, 3H), 7.07 (d, J = 7.6 Hz, 1H), 3.52 (s, 3H), 2.30 (s, 3H); 13C NMR (100 MHz, CDCl3): δ 170.0, 139.8, 138.8, 135.6, 132.9, 131.4, 129.8, 129.5, 129.4, 127.0, 121.7, 51.9, 19.6. GCMS, m/z (% relative intensity, ion): 306[M+2⁺] (30), 304[M⁺] (32), 275 (23), 273 (24), 194 (91), 193 (40), 165 (100). IR: ν = 2947, 1724, 1589, 1458, 1435, 1265, 1238, 1119, 1069, 787.

Methyl 3’-bromo-3-methylbiphenyl-2-carboxylate (3o) [CAS: 1809272-66-9]

Compound 3o was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 1-bromo-3-iodobenzene (211.5 mg, 0.75 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 3o and 3o’ were obtained as brown oil with about 7:1 ratio (62.3 mg, 82% isolated yield). 1H NMR (400 MHz, CDCl3): δ 7.52 (t, J = 1.6 Hz, 1H), 7.45 (dt, J = 7.6 Hz, 1.8 Hz, 1H), 7.35 (t, J = 7.8 Hz, 1H), 7.29–7.26 (m, 1H), 7.25–7.22 (m, 2H), 7.18 (d, J = 7.6 Hz, 1H), 3.62 (s, 3H), 2.39 (s, 3H); 13C NMR (100 MHz, CDCl3): δ 169.9, 142.9, 138.5, 135.7, 133.1, 131.3, 130.4, 129.8, 129.7, 129.5, 127.1, 126.9, 122.3, 51.9, 19.7. GCMS, m/z (% relative intensity, ion): 306[M+2⁺] (25), 304 [M⁺] (27), 275 (22), 273 (22), 194 (84), 165 (100), 139 (12). IR: ν = 2947, 1724, 1589, 1555, 1454, 1265, 1238, 1123, 1099, 1065, 775.

Methyl 2-methyl-6-(thiophen-3-yl)benzoate (3p)

Compound 3p was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 3-bromothiophene (60.8 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 3p was obtained as light yellow solid
(46.4 mg, 80% isolated yield). m.p. = 65 – 66 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.36 – 7.36 (m, 2H), 7.31 – 7.28 (m, 2H), 7.19 (d, \(J = 8.0\) Hz, 1H), 7.16 (dd, \(J = 8.0\) Hz, 4.0 Hz, 1H), 3.70 (s, 3H), 2.38 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 170.5, 140.9, 135.2, 134.3, 133.0, 129.3, 129.0, 127.9, 126.8, 125.6, 122.3, 52.0, 19.5. GCMS, m/z (% relative intensity, ion): 232[M\(^+\)] (56), 200 (100), 171 (78), 158 (20), 129 (31), 115 (19), 102 (6). IR: \(\tilde{\nu}\) = 2924, 1728, 1258, 1119, 1065, 772.

**Methyl 2-methyl-6-(1-methyl-1H-pyrazol-4-yl)benzoate (3q)**

![Methyl 2-methyl-6-(1-methyl-1H-pyrazol-4-yl)benzoate (3q)](image)

Compound 3q was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 3-iodo-1-methyl-1H-pyrazole (78 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 5: 1), 3q was obtained as colorless liquid (47.2 mg, 82% isolated yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.55 (s, 1H), 7.28 (t, \(J = 8.0\) Hz, 1H), 7.20 (d, \(J = 8.0\) Hz, 1H), 7.12 (d, \(J = 8.0\) Hz, 1H), 3.91 (s, 3H), 3.79 (s, 3H), 2.33 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 170.8, 138.0, 134.9, 132.6, 129.9, 129.4, 128.4, 128.3, 126.3, 121.1, 52.1, 39.0, 19.4. GCMS, m/z (% relative intensity, ion): 230[M\(^+\)] (100), 198 (83), 184 (17), 169 (16), 155 (25), 130 (15), 115 (21), 103 (23), 77 (14). IR: \(\tilde{\nu}\) = 2947, 1724, 1593, 1439, 1265, 1099, 1069, 787.

**Methyl 2-methyl-6-(1-methyl-1H-indol-5-yl)benzoate (3r)**

![Methyl 2-methyl-6-(1-methyl-1H-indol-5-yl)benzoate (3r)](image)

Compound 3r was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 5-iodo-1-methyl-1H-indole (96.4 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 3r was obtained as yellow solid (65.5 mg, 94% isolated yield). m.p. = 83 – 84 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.66 (s, 1H), 7.39 – 7.34 (m, 2H), 7.32 (d, \(J = 8.0\) Hz, 1H), 7.28 (dd, \(J = 8.4\) Hz, 1.6 Hz, 1H), 7.21 (d, \(J = 7.2\) Hz, 1H), 7.09 (d, \(J = 2.8\) Hz, 1H), 6.52 (d, \(J = 3.2\) Hz, 1H), 3.82 (s, 3H), 3.60 (s, 3H), 2.44 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 170.8, 141.2, 136.1, 135.1, 133.5, 132.1,
129.3, 129.2, 128.5, 128.3, 127.7, 120.5, 109.0, 101.2, 51.8, 32.8, 19.7. GCMS, m/z (%
relative intensity, ion): 279[M⁺] (100), 247 (73), 233 (16), 218 (11), 204 (15), 178 (6), 151 (5),
139 (6), 124 (8), 102 (15), 97 (26). IR: \( \tilde{\nu} = 2978, 1728, 1265, 1242, 787. \)

**Methyl 2-(6-chloro-5-methylpyridin-3-yl)-6-methylbenzoate (3s)**

![Methyl 2-(6-chloro-5-methylpyridin-3-yl)-6-methylbenzoate](image)

Compound 3s was prepared following the general procedure, starting from 2-methoxybenzoic
acid (35 mg, 0.25 mmol) and 5-bromo-2-chloro-3-methylpyridine (76.9 mg, 0.375 mmol).
After purification by column chromatography (ethyl acetate / hexane = 5: 1), 3s was obtained
as yellow liquid (28.9 mg, 42% isolated yield). \(^1^H\) NMR (400 MHz, CDCl\(_3\)): \( \delta \) 8.22 (d, \( J = 1.6 \)
Hz, 1H), 7.55 (s, 1H), 7.39 (t, \( J = 7.6 \) Hz, 1H), 7.80 (d, \( J = 8.0 \) Hz, 1H), 7.16 (d, \( J = 7.2 \) Hz, 1H), 3.67 (s, 3H), 2.41 (s, 3H), 2.40 (s, 3H); \(^1^C\) NMR (100 MHz, CDCl\(_3\)): \( \delta \) 169.6, 150.7, 146.0, 139.0, 136.0, 135.7, 135.2, 133.2, 131.9, 130.2, 129.7, 127.2, 52.1, 19.7, 19.6. GCMS,
m/z (% relative intensity, ion): 277[M+2⁺] (11), 275[M⁺] (34), 260 (4), 244 (100), 208 (9), 180
(13), 166 (9), 152 (16), 139 (5), 115 (6), 76 (7). IR: \( \tilde{\nu} = 1725, 1591, 1387, 1166, 1103, 956. \)

**Methyl 2-(6-chloropyridin-3-yl)-6-ethylbenzoate (3t)**

![Methyl 2-(6-chloropyridin-3-yl)-6-ethylbenzoate](image)

Compound 3t was prepared following the general procedure (using EtI instead of MeI for
esterification), starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 5-bromo-2-
chloropyridine (71.6 mg, 0.375 mmol). After purification by column chromatography (ethyl
acetate / hexane = 5: 1), 3t was obtained as yellow liquid (78% isolated yield). \(^1^H\) NMR
(400 MHz, CDCl\(_3\)): \( \delta \) 8.37 (d, \( J = 2.4 \) Hz, 1H), 7.64 (dd, \( J = 8.0 \) Hz, 2.4 Hz, 1H), 7.39 - 7.32
(m, 2H), 7.27 (d, \( J = 7.6 \) Hz, 2H), 7.14 (d, \( J = 7.2 \) Hz, 1H), 4.12 (q, \( J = 7.2 \) Hz, 2H), 2.40 (s,
3H), 1.07 (t, \( J = 7.2 \) Hz, 3H); \(^1^C\) NMR (100 MHz, CDCl\(_3\)): \( \delta \) 168.8, 150.4, 148.8, 138.5, 136.0,
135.5, 135.0, 133.4, 130.3, 129.6, 127.1, 123.6, 61.1, 19.6, 13.8. GCMS, m/z (% relative
intensity, ion): 277[M+2⁺] (10), 275[M⁺] (29), 246 (9), 230 (100), 219 (5), 203 (7), 194 (9),
166 (29), 139 (22), 115 (9), 89 (5). IR: \( \tilde{\nu} = 2982, 2361, 1720, 1589, 1450, 1261, 1126, 1088,
1065, 1023, 791 \text{ cm}^{-1} \)
Methyl 2-(2-chloropyridin-4-yl)-6-methylbenzoate (3u)

Compound 3u was prepared following procedure B, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 4-bromo-2-chloropyridine (71.6 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 5: 1), 3x was obtained as brown oil (42.4 mg, 65% isolated yield). $^1$H NMR (400 MHz, CDCl3): $\delta$ 8.39 (d, $J = 4.8$ Hz, 1H), 7.40 (t, $J = 7.6$ Hz, 1H), 7.33 – 7.30 (m, 2H), 7.20 – 7.17 (m, 2H), 3.65 (s, 3H), 2.41 (s, 3H); $^{13}$C NMR (100 MHz, CDCl3): $\delta$ 169.2, 151.9, 151.7, 149.4, 136.4, 136.1, 132.6, 131.0, 129.9, 126.6, 123.5, 121.9, 52.1, 19.7. GCMS, m/z (% relative intensity, ion): 263[M+2$^+$] (18), 261[M$^+$] (52), 230 (100), 202 (8), 194 (17), 166 (21), 139 (26), 115 (10), 89 (5). IR: $\tilde{\nu}$ = 2928, 2361, 1724, 1589, 1535, 1373, 1265, 1123, 1096, 1069, 791, 768.

Methyl 2-(6-chloro-5-fluoropyridin-3-yl)-6-methylbenzoate (3v)

Compound 3v was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 5-bromo-2-chloro-3-fluoropyridine (78.4 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 5: 1), 3v was obtained as yellow liquid (50.9 mg, 73% isolated yield). $^1$H NMR (400 MHz, CDCl3): $\delta$ 8.20 (d, $J = 1.2$ Hz, 1H), 7.49 (dd, $J = 8.8$ Hz, 2 Hz, 1H), 7.41 (t, $J = 8.0$ Hz, 1H), 7.31 (d, $J = 7.6$ Hz, 1H), 7.16 (d, $J = 7.6$ Hz, 1H), 3.69 (s, 3H), 2.41 (s, 3H); $^{13}$C NMR (100 MHz, CDCl3): 169.2, 154.2 (d, $J = 130.5$ Hz, 1C), 143.8 (d, $J = 5$ Hz, 1C), 137.95 (d, $J = 9.5$ Hz, 1C), 137.5 (d, $J = 2$ Hz, 1C), 136.4, 133.8, 133.1, 130.8, 129.9, 127.1, 124.2 (d, $J = 19$ Hz, 1C), 52.2, 19.7. $^{19}$F NMR (376 MHz, CDCl3): $\delta$ -56.33 (d, $J = 7.5$ Hz, 1F). GCMS, m/z (% relative intensity, ion): 281[M+2$^+$] (9), 279[M$^+$] (28), 250 (36), 248 (100), 184 (20), 158 (10), 91 (5). IR: $\tilde{\nu}$ = 2951, 2361, 1724, 1593, 1439, 1393, 1265, 1126, 1103, 1076, 791.

Methyl 2-(5-bromo-6-chloropyridin-3-yl)-6-methylbenzoate (3w)
Compound 3w was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 3,5-dibromo-2-chloropyridine (100.9 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 5: 1), 3w was obtained as yellow solid (46.6 mg, 55% isolated yield). m.p. = 87 – 88 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 8.32 (d, \(J = 1.6\) Hz, 1H), 7.94 (d, \(J = 2.0\) Hz, 1H), 7.40 (t, \(J = 8.4\) Hz, 1H), 7.30 (d, \(J = 7.6\) Hz, 1H), 7.16 (d, \(J = 7.6\) Hz, 1H), 3.70 (s, 3H), 2.40 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 169.2, 149.7, 146.9, 146.1, 136.8, 136.4, 133.7, 133.1, 130.8, 129.9, 127.1, 119.7, 52.2, 19.8. GCMS, m/z (% relative intensity, ion): 341[M+2\(^+\)] (27), 339[M\(^+\)] (22), 310 (100), 308 (72), 229 (28), 201 (11), 166 (29), 139 (20), 115 (5), 82 (10). IR: \(\nu\) = 2928, 2360, 1713, 1269.

**Methyl 3-methyl-3’-(pyrrolidine-1-carbonyl)biphenyl-2-carboxylate (3x)**

Compound 3x was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and (3-iodophenyl)(pyrrolidin-1-yl)methanone (112.9 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 5: 1), 3x was obtained as light yellow solid (76.8 mg, 95% isolated yield). m.p. = 135 – 137 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 7.49 – 7.47 (m, 2H), 7.33 (d, \(J = 8.0\) Hz, 1H), 7.19 (dd, \(J = 12.0\) Hz, 8.0 Hz, 2H), 3.62 (t, \(J = 8.0\) Hz, 2H), 3.57 (s, 3H), 3.41 (t, \(J = 8.0\) Hz, 2H), 2.37 (s, 3H), 1.96–1.90 (m, 2H), 1.88–1.83 (m, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta\) 170.0, 169.2, 140.7, 139.2, 137.3, 135.4, 133.0, 129.4, 129.3, 128.2, 127.1, 126.8, 126.1, 51.8, 49.5, 46.1, 26.3, 24.3, 19.6. MS (APCI+), m/z: 323.85 [M+H\(^+\)]. IR: \(\nu\) = 2951, 1724, 1620, 1431, 1269, 1119, 1069, 748.

**3’-(Diethylcarbamoyl)-3-methylbiphenyl-2-carboxylic acid (3y)**

Compound 3y was prepared following the general procedure, starting from 2-methoxybenzoic acid (35 mg, 0.25 mmol) and 3-bromo-N,N-diethylbenzamide (95.6 mg, 0.375 mmol). After the
reaction was complete, the reaction mixture was allowed to cool to rt. The reaction mixture was
diluted with ethyl acetate (20 mL) and extracted with aq. NaOH solution (3 × 20 mL). The aq.
basic phase was acidified with HCl (pH 1-2) and afterwards extracted with ethyl acetate (3 ×
20 mL). The combined organic layers were dried over MgSO₄, filtered, and the volatiles were
removed under reduced pressure. The residue was purified by column chromatography (SiO₂,
ethyl acetate/hexane = 5:1, 1% formic acid) yielding 3y as beige solid (50.9 mg, 65% isolated
yield). ¹H NMR (400 MHz, CDCl₃): δ 7.43–7.31 (m, 4H), 7.29 (d, J = 4.4 Hz, 1H), 7.20 (d, J =
7.6 Hz, 1H), 7.15 (d, J = 7.6 Hz, 1H), 3.49 (d, J = 5.6 Hz, 2H), 3.24 (d, J = 6.0 Hz, 2H), 2.38
(s, 3H), 1.19–1.06 (m, 6H); ¹³C NMR (100 MHz, CDCl₃): δ 172.1, 171.5, 141.1, 138.9, 136.3,
135.4, 133.4, 129.4, 129.2, 128.5, 127.1, 126.2, 125.1, 43.5, 39.5, 19.8, 14.1, 12.8. MS (APCI+),
m/z: 312.85 [M+H⁺]. IR: ν = 2970, 2928, 2160, 1717, 1620, 1543, 1273, 1123, 768.

Methyl 4’-(isopropylcarbamoyl)-3-methylbiphenyl-2-carboxylate (3z)

Compound 3z was prepared following the general procedure, starting from 2-methoxybenzoic
acid (35 mg, 0.25 mmol) and 4-bromo-N-isopropylbenzamide (90.4 mg, 0.375 mmol). After
purification by column chromatography (ethyl acetate / hexane = 5: 1), 3z was obtained as white
solid (42.3 mg, 54% isolated yield). m.p. = 170 – 172 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.78
d, J = 8.0 Hz, 2H), 7.38 – 7.36 (m, 2H), 7.34 (t, J = 8.0 Hz, 1H), 7.22 (d, J = 8.0 Hz, 1H), 7.16
(d, J = 8.0 Hz, 1H), 7.32 – 7.28 (m, 2H), 6.20 (d, J = 8.0 Hz, 1H), 6.29 (dt, J = 12.0 Hz, 8.0 Hz,
1H), 3.56 (s, 3H), 2.38 (s, 3H), 1.25 (d, J = 8.0 Hz, 6H); ¹³C NMR (100 MHz, CDCl₃): δ 169.9,
166.3, 143.8, 139.0, 135.6, 133.7, 132.9, 129.6, 129.5, 128.2, 127.0, 126.8, 51.9, 41.8, 22.7,
19.6. MS (APCI+), m/z: 312.85 [M+H⁺]. IR: ν = 2967, 2928, 2160, 1705, 1574, 1458, 1254,
787.

Methyl 4-(trifluoromethyl)biphenyl-2-carboxylate (4ba)

Compound 4ba was prepared following the general procedure, starting from 3-(trifluoromethyl)benzoic acid (47.5 mg, 0.25 mmol) and phenyl iodide (76.5 mg, 0.375 mmol).
After purification by column chromatography (ethyl acetate / hexane = 10: 1), 4ba was obtained as beige solid (54.6 mg, 78% isolated yield). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 8.11 (s, 1H), 7.79 (d, $J$ = 8.0 Hz, 1H), 7.52 (d, $J$ = 8.0 Hz, 1H), 7.45 - 7.42 (m, 3H), 7.33 - 7.31 (m, 2H), 3.68 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 167.8, 146.0, 139.9, 131.4, 131.3, 129.6 (q, $J$ = 26 Hz), 128.2, 128.1, 128.0, 127.8 (q, $J$ = 3.6 Hz), 126.9 (q, $J$ = 217 Hz), 126.7 (q, $J$ = 3.9 Hz), 52.3. $^{19}$F NMR (376 MHz, CDCl$_3$): $\delta$ 0.23 (s, 3F). GCMS, m/z (% relative intensity, ion): 280[M$^+$] (46), 261 (5), 249 (100), 201 (29), 152 (26), 125. IR: $\tilde{v}$ = 2955, 2361, 1728, 1335, 1242, 1169, 1123, 1084, 768.

**Methyl 4-bromobiphenyl-2-carboxylate (4ca) [CAS: 493028-83-4]**

\[
\text{Br} \quad \text{CO}_2\text{Me}
\]

Compound 4ca was prepared following the general procedure, starting from 3-bromobenzoic acid (50.0 mg, 0.25 mmol) and phenyl iodide (76.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 4ca was obtained as colorless liquid (45.1 mg, 62% isolated yield). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.99 (d, $J$ = 2.0 Hz, 1H), 7.67 (dd, $J$ = 8.4 Hz, 2.0 Hz, 1H), 7.44 - 7.38 (m, 3H), 7.31 - 7.28 (m, 3H), 3.67 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 167.6, 141.4, 140.1, 134.2, 132.6, 132.4, 132.3, 128.2, 127.6, 121.01, 52.2. GCMS, m/z (% relative intensity, ion): 292[M$^+$] (61), 290[M$^+$] (69), 261 (66), 259 (64), 180 (55), 152 (100), 126 (12), 99 (9), 76 (32). IR: $\tilde{v}$ = 2951, 1720, 1435, 1277, 1238, 1142, 1092, 760, 698.

**Methyl 4-chlorobiphenyl-2-carboxylate (4da) [CAS: 1092775-67-1]**

\[
\text{Cl} \quad \text{CO}_2\text{Me}
\]

Compound 4da was prepared following procedure B, starting from 3-chlorobenzoic acid (39 mg, 0.25 mmol) and phenyl iodide (76.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 4da was obtained as yellow liquid (41.8 mg, 68% isolated yield). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.82 (d, $J$ = 2.0 Hz, 1H), 7.50 (dd, $J$ = 8.4 Hz, 2.0 Hz, 1H), 7.42 - 7.37 (m, 3H), 7.32 (d, $J$ = 8.0 Hz, 1H), 7.28 (dd, $J$ = 8.0 Hz, 1.2Hz,

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$^5$ Wang, Y.; Gulevich, A. V.; Gevorgyan, V. Chem. – Eur. J., 2013, 19, 15836-15840.

$^6$ Ramirez, N. P.; Bosque, I.; Gonzalez-Gomez, J. C., Org. Lett., 2015, 17, 4550-4553.
2H), 3.65 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 167.8, 140.9, 140.1, 133.2, 132.1, 132.0, 131.2, 129.7, 128.2, 128.1, 127.5, 52.2. GCMS, m/z (% relative intensity, ion): 248[M+2$^+$] (26), 246[M$^+$] (68), 215 (95), 152 (100), 76 (18). IR: $\tilde{\nu}$ = 2951, 2361, 1720, 1435, 1277, 1238, 1088, 764, 698.

Methyl 4-methylbiphenyl-2-carboxylate (4ea) [CAS: 152620-33-2]$^5$

![Me-CO$_2$Me]

Compound 4ea was prepared following procedure B, starting from 3-methylbenzoic acid (35 mg, 0.25 mmol) and phenyl iodide (76.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 4ea was obtained as colorless oil (53.1 mg, 94% isolated yield). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.65 (s, 1H), 7.42 – 7.39 (m, 1H), 7.38 – 7.27 (m, 6H), 3.64 (s, 3H), 2.43 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 169.3, 141.2, 139.6, 137.0, 132.0, 130.61, 130.58, 130.2, 128.3, 128.0, 127.0, 51.8, 20.9. GCMS, m/z (% relative intensity, ion): 226[M$^+$] (100), 195(95), 165 (54), 152 (64), 139 (7), 115 (9). IR: $\tilde{\nu}$ = 2947, 2361, 1717, 1435, 1296, 1204, 1088, 764.

Methyl 4-acetylbiphenyl-2-carboxylate (4fa) [CAS: 537715-93-8]$^7$

![O-CO$_2$Me]

Compound 4fa was prepared following procedure B, starting from 3-acetylbenzoic acid (41 mg, 0.25 mmol) and phenyl iodide (76.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 4fa was obtained as colorless oil (63.5 mg, 99% isolated yield). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 8.39 (d, $J = 1.6$ Hz, 1H), 8.10 (dd, $J = 8.0$ Hz, 1.6 Hz, 1H), 7.49 (d, $J = 8.4$ Hz, 1H), 7.44 – 7.39 (m, 3H), 7.33 – 7.31 (m, 2H), 3.67 (s, 3H), 2.66 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 196.8, 168.3, 146.8, 140.1, 135.7, 131.2, 131.1, 130.6, 129.9, 128.2, 128.1, 127.9, 52.2, 26.6. GCMS, m/z (% relative intensity, ion): 254[M$^+$] (51), 239 (100), 223 (12), 196 (5), 152 (18), 139 (7), 76 (4). IR: $\tilde{\nu}$ = 2951, 2361, 1721, 1686, 1231, 1096, 768, 702.

$^5$ Takasugi, H.; Inoue, Y.; Yoshikazu, T.; etc. PCT Int. Appl., 2003045921, 05 Jun 2003.

S22
Methyl 4-iodobiphenyl-2-carboxylate (4ga) [CAS: 69240-47-7]

Compound 4ga was prepared following the general procedure, starting from 3-iodobenzoic acid (62 mg, 0.25 mmol) and phenyl iodide (76.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 4ga was obtained as yellow oil (42.2 mg, 50% isolated yield). 1H NMR (400 MHz, CDCl₃): δ 8.16 (d, J = 1.6 Hz, 1H), 7.85 (dd, J = 8.0 Hz, 2.0 Hz, 2H), 7.43 - 7.37 (m, 3H), 7.28 (dd, J = 7.6 Hz, 1.6 Hz, 2H), 7.11 (d, J = 8.0 Hz, 1H), 3.64 (s, 3H); 13C NMR (100 MHz, CDCl₃): δ 167.5, 141.9, 140.13, 140.10, 138.4, 132.5, 132.4, 128.1, 128.1, 127.6, 92.2, 52.2. GCMS, m/z (% relative intensity, ion): 338[M⁺] (100), 307 (80), 196 (7), 180 (47), 152 (76), 139 (13), 102 (7), 76 (14). IR: v = 2947, 1721, 1466, 1435, 1277, 1238, 1088, 760, 698.

Methyl 2-phenyl-1-naphthoate (4ha) [CAS: 109251-89-0]

Compound 4ha was prepared following the general procedure, starting from 1-naphthoic acid (43 mg, 0.25 mmol) and phenyl iodide (76.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 4ha was obtained as yellow oil (63.5 mg, 97% isolated yield). 1H NMR (400 MHz, CDCl₃): δ 7.98 (dd, J = 12 Hz, 8.4 Hz, 2H), 7.91 (d, J = 8.0 Hz, 1H), 7.62 - 7.58 (m, 1H), 7.57 - 7.45 (m, 6H), 7.42 - 7.39 (m, 1H), 3.72 (s, 3H). 13C NMR (100 MHz, CDCl₃): δ 170.0, 140.9, 138.0, 132.3, 129.92, 129.89, 128.5, 128.4 (2C), 128.1, 127.6, 127.42, 127.36, 126.3, 125.0, 52.1. GCMS, m/z (% relative intensity, ion): 262[M⁺] (67), 231 (100), 202 (38), 101 (23), 88 (7). IR: v = 2947, 1721, 1435, 1231, 1138, 826, 760, 703.

Methyl 3-ethoxybiphenyl-2-carboxylate (4ia)

Hawkins, A. F.; Jones, I.; Lewis, T., U.S. (1980), US 4242121 A 19801230.
Zhao, Y.; Snieckus, V., Chem. Commun., 2016, 52, 1681-1684.
Compound **4ia** was prepared following the general procedure, starting from 2-ethoxybenzoic acid (42 mg, 0.25 mmol) and phenyl iodide (76.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), **4ia** was obtained as yellow solid (61 mg, 95% isolated yield). m.p. = 73 – 74 °C. $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.42 – 7.34 (m, 6H), 6.98 (d, $J$ = 8.0 Hz, 1H), 6.93 (d, $J$ = 8.0 Hz, 1H), 4.12 (q, $J$ = 8.0 Hz, 2H), 3.65 (s, 3H), 1.42 (t, $J$ = 7.2 Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 168.5, 155.8, 141.1, 140.1, 130.4, 128.3, 128.2, 127.5, 123.5, 121.8, 111.0, 64.5, 51.9, 14.7. GCMS, m/z (% relative intensity, ion): 256[M$^+$] (98), 225 (87), 196 (100), 168 (96), 141 (27), 139 (73), 115 (27). IR: $\tilde{\nu}$ = 2924, 1728, 1253, 1165, 1119, 783.

**Methyl 3-phenylbiphenyl-2-carboxylate (4ja) [CAS: 19832-92-9]**$^{10}$

![Phenylbiphenyl-2-carboxylate](image)

Compound **4ja** was prepared following the general procedure, starting from biphenyl-2-carboxylic acid (50 mg, 0.25 mmol) and phenyl iodide (76.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), **4ja** was obtained as white solid (65.5 mg, 91% isolated yield). m.p. = 120 – 121 °C. $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.53 (dd, $J$ = 8.4 Hz, 7.6 Hz, 1H), 7.44–7.38 (m, 12H), 3.41 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 169.8, 140.5, 140.3, 132.8, 129.3, 128.8, 128.3, 127.5, 113 (8), 101 (7). IR: $\tilde{\nu}$ = 2947, 1724, 1439, 1281, 1250, 748, 702.

**Methyl 3-phenylthiophene-2-carboxylate (4ka) [CAS: 21676-89-1]**$^{11}$

![Thiophene-2-carboxylate](image)

Compound **4ka** was prepared following the general procedure, starting from thiophene-2-carboxylic acid (32 mg, 0.25 mmol) and phenyl iodide (76.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), **4ka** was obtained as white solid (44.1 mg, 81% isolated yield). m.p. = 117 – 118 °C. $^1$H NMR (400 MHz, CDCl$_3$):

$^{10}$ Moß, G.; Ladzik, S.; Reinke, H.; Spannenberg, A.; Fischer, C.; Langer, P., *Synthesis*, 2009, 2236-2248.

$^{11}$ Yang, J.; Liu, S.; Zheng, J.-F.; Zhou, J., *Eur. J. Org. Chem.*, 2012, 3248-6259.
\[ \delta 7.51 (d, J = 8.0 \text{ Hz}, 1H), 7.48 - 7.46 \text{ (m}, 2H), 7.44 - 7.38 \text{ (m}, 3H), 7.10 \text{ (d}, J = 5.2 \text{ Hz}, 1H), 3.78 \text{ (s}, 3H) \]; $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 162.4, 148.7, 135.6, 131.5, 130.2, 129.2, 127.9, 127.8, 126.9, 51.9. GCMS, m/z (% relative intensity, ion): 218[M$^+$] (91), 187 (85), 159 (18), 115 (100), 89 (17), 79 (12). IR: $\tilde{\nu}$ = 2924, 1705, 1439, 1281, 1234, 1119, 1088, 752.

**Methyl 3-(6-chloropyridin-3-yl)thiophene-2-carboxylate (4kt)**

Compound 4kt was prepared following the general procedure, starting from thiophene-2-carboxylic acid (32 mg, 0.25 mmol) and 5-bromo-2-chloropyridine (71.6 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 5: 1), 4kt was obtained as colorless solid (13.3 mg, 21% isolated yield). m.p. = 149 - 151 °C. $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 8.44 (d, $J = 2.0$ Hz, 1H), 7.79 (dd, $J = 8.0$ Hz, 2.0 Hz, 1H), 7.58 (d, $J = 5.2$ Hz, 1H), 7.37 (d, $J = 8.4$ Hz, 1H), 7.08 (d, $J = 2.0$ Hz, 1H), 3.80 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 162.0, 150.8, 149.4, 143.2, 139.6, 131.2, 130.9, 130.4, 128.4, 123.3, 52.2. GCMS, m/z (% relative intensity, ion): 255[M$+2^+$] (38), 253[M$^+$] (100), 224 (35), 222 (91), 186 (31), 159 (22), 114 (20), 94 (12). IR: $\tilde{\nu}$ = 1708, 1463, 1431, 1243, 1226, 1080, 892, 833.

**Methyl 2,6-dimethyl-4-phenylnicotinate (4la)**

Compound 4la was prepared following the general procedure, starting from 2,6-dimethylnicotinic acid (38 mg, 0.25 mmol) and phenyl iodide (76.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 5: 1), 4la was obtained as yellow solid (32.5 mg, 54% isolated yield). m.p. = 31–32 °C $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.41–7.38 (m, 3H), 7.35–7.33 (m, 2H), 7.02 (s, 1H), 3.60 (s, 3H), 2.59 (s, 3H), 2.57 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 169.6, 158.8, 155.1, 148.3, 138.6, 128.5, 128.4, 127.7, 125.4, 121.1, 52.1, 24.4, 22.8. GCMS, m/z (% relative intensity, ion): 241[M$^+$] (72), 210 (100), 182 (11), 167 (18), 139 (13), 115 (33). IR: $\tilde{\nu}$ = 1727, 1589, 1266, 1212, 1137.

7-Methyl-6H-benzo[c]chromen-6-one (6a) [CAS: 106737-97-7]$^4$
Compound 6a was prepared following the general procedure, starting from 2-methylbenzoic acid (35 mg, 0.25 mmol) and 2-iodophenol (82.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 6a was obtained as white solid (49.8 mg, 95% isolated yield). m.p. = 101 – 102 °C. $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.96 (q, $J$ = 8.0 Hz, 2H), 7.62 (t, $J$ = 8.0 Hz, 2H), 7.44 – 7.40 (m, 1H), 7.34 (d, $J$ = 8.0 Hz, 1H), 7.29 – 7.25 (m, 2H), 2.84 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 160.3, 151.2, 144.3, 136.0, 133.8, 132.1, 130.1, 124.1, 122.9, 119.7, 119.6, 118.2, 117.2, 23.8. GCMS, m/z (% relative intensity, ion): 210[M$^+$] (100), 181 (38), 165 (10), 152 (35), 127 (6), 105 (7), 76 (18). IR: $\nu$ = 2924, 2507, 2160, 1717, 1462, 1246, 1246, 1207, 1065, 752.

6H-benzo[c]chromen-6-one (6b) [CAS: 2005-10-9]$^{12}$

Compound 6b was prepared following the general procedure, starting from benzoic acid (31 mg, 0.25 mmol) and 2-iodophenol (82.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 6b was obtained as white solid (35.3 mg, 72% isolated yield). m.p. = 93 – 94 °C. $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 8.38 (d, $J$ = 8.0 Hz, 2H), 8.10 (d, $J$ = 8.0 Hz, 2H), 8.04 (d, $J$ = 8.0 Hz, 1H), 7.81 (t, $J$ = 8.0 Hz, 2H), 7.57 (t, $J$ = 8.0 Hz, 1H), 7.49 -7.45 (m, 1H), 7.36 – 7.30 (m, 1H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 161.1, 151.2, 134.8, 134.7, 130.5, 130.4, 128.8, 124.5, 122.7, 121.6, 121.2, 118.0, 117.7. GCMS, m/z (% relative intensity, ion): 196[M$^+$] (100), 168 (65), 139 (81), 113 (12), 98 (11), 84 (8). IR: $\nu$ = 2924, 2160, 1728, 1605, 1261, 1076, 1030, 745, 718.

8-Acetyl-6H-benzo[c]chromen-6-one (6c) [CAS: 1447543-99-8]$^{13}$

$^{12}$ Zhang, Z.; Gao, Y.; Liu, Y.; Li, J.; Xie, H.; Li, H.; Wang, W., Org. Lett., 2015, 17, 5492-5495.
$^{13}$ Luo, S.; Luo, F.-X; Zhang, X.-S.; Shi, Z.-J., Angew. Chem. Int. Ed., 2013, 52, 10598-10601.
Compound 6c was prepared following the general procedure, starting from 3-acetylbenzoic acid (41 mg, 0.25 mmol) and 2-iodophenol (82.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1), 6c was obtained as light yellow solid (51.7 mg, 92% isolated yield). m.p. = 185 – 186 °C. 1H NMR (400 MHz, CDCl3): δ 8.87 (d, J = 1.6 Hz, 1H), 8.38 (dd, J = 8.4 Hz, 1.6 Hz, 1H), 8.17 (d, J = 8.4 Hz, 1H), 8.06 (d, J = 7.2 Hz, 1H), 7.55 – 7.51 (m, 1H), 7.38 – 7.34 (m, 2H), 2.69 (s, 3H); 13C NMR (100 MHz, CDCl3): δ 196.2, 160.5, 151.7, 138.4, 136.9, 133.5, 131.8, 131.2, 124.9, 123.4, 122.3, 121.1, 117.9, 117.2, 26.6. GCMS, m/z (% relative intensity, ion): 238[M+] (9), 223 (17), 211 (100), 183 (17), 155 (26), 154 (61), 139 (13), 127 (23), 77 (16). IR: ν = 2924, 2160, 1975, 1717, 1601, 1308, 826, 745.

8-Chloro-6H-benzo[c]chromen-6-one (6d)

8-Chloro-6H-benzo[c]chromen-6-one (6d) was prepared following the general procedure, starting from 3-chlorobenzoic acid (39 mg, 0.25 mmol) and 2-iodophenol (82.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1, 6d was obtained as brown solid (55.2 mg, 96% isolated yield). m.p. = 174 – 175 °C. 1H NMR (400 MHz, CDCl3): δ 8.30 (d, J = 2.0 Hz, 1H), 8.02 (d, J = 8.8 Hz, 2H), 7.98 – 7.96 (m, 1H), 7.73 (dd, J = 8.4 Hz, 2.0 Hz, 1H), 7.48 (t, J = 7.6 Hz, 1H), 7.35 – 7.31 (m, 2H); 13C NMR (100 MHz, CDCl3): δ 159.9, 151.0, 135.0, 134.9, 133.1, 130.8, 129.9, 124.8, 123.3, 122.7, 122.4, 117.8, 117.2. GCMS, m/z (% relative intensity, ion): 232[M+2+] (34), 230[M+] (100), 202 (23), 139 (51), 87 (7), 69 (9). IR: ν = 2928, 2160, 1975, 1717, 1601, 1308, 826, 745.

9-Bromo-6H-benzo[c]chromen-6-one (6e) [CAS: 1469912-47-7]14

9-Bromo-6H-benzo[c]chromen-6-one (6e) was prepared following the general procedure, starting from 4-bromobenzoic acid (50 mg, 0.25 mmol) and 2-iodophenol (82.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 10: 1, 6e was obtained as white solid (59.6 mg, 91% isolated yield). m.p. = 192 °C. 1H NMR (400 MHz, CDCl3): δ 8.85 (d, J = 1.6 Hz, 1H), 8.28 (dd, J = 8.4 Hz, 1.6 Hz, 1H), 8.18 (d, J = 8.4 Hz, 1H), 8.06 (d, J = 7.2 Hz, 1H), 7.55 – 7.51 (m, 1H), 7.38 – 7.34 (m, 2H), 2.69 (s, 3H); 13C NMR (100 MHz, CDCl3): δ 196.2, 160.5, 151.7, 138.4, 136.9, 133.5, 131.8, 131.2, 124.9, 123.4, 122.3, 121.1, 117.9, 117.2, 26.6. GCMS, m/z (% relative intensity, ion): 238[M+] (9), 223 (17), 211 (100), 183 (17), 155 (26), 154 (61), 139 (13), 127 (23), 77 (16). IR: ν = 2924, 2160, 1975, 1717, 1601, 1308, 826, 745.

14 Zhou, J.; Han, P.; Xu, Y.-M.; Zhang, T.; Du, Z.-T., Heterocycles, 2013, 87, 1889-1896.
7-(Methylamino)-6H-benzo[c]chromen-6-one (6f)

Compound 6f was prepared following the general procedure, starting from 2-(methylamino)benzoic acid (37.8 mg, 0.25 mmol) and 2-iodophenol (82.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 5: 1), 6f was obtained as brown solid (29.2 mg, 52% isolated yield). m.p. = 143 – 144 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta \) 8.49 (s, 1H), 7.97 (d, \(J = 8.0 \text{ Hz}, 1\H), 7.57 (t, \(J = 8.0 \text{ Hz}, 1\H), 7.42 (t, \(J = 8.0 \text{ Hz}, 1\H), 7.29–7.26 (m, 2H), 7.24 (d, \(J = 8.0 \text{ Hz}, 1\H), 6.67 (d, \(J = 8.0 \text{ Hz}, 1\H), 2.97 (d, \(J = 5.2 \text{ Hz}, 3\H); \(^1\)C NMR (100 MHz, CDCl\(_3\)): \(\delta \) 163.4, 153.1, 150.9, 136.2, 136.0, 129.9, 124.2, 123.3, 118.8, 117.2, 109.4, 107.2, 102.9, 29.7. GCMS, m/z (% relative intensity, ion): 225[M\(^+\)] (100), 224 (51), 196 (21), 168 (20), 139 (24), 113 (9), 98 (5). IR: \(\tilde{\nu} = 2924, 2160, 1975, 1686, 1574, 1443, 1250, 1096, 748.

8-Amino-6H-benzo[c]chromen-6-one (6g) [CAS: 27421-12-1]\(^{15}\)

Compound 6g was prepared following the general procedure, starting from 3-aminobenzoic acid (34.5 mg, 0.25mmol) and 2-iodophenol (82.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 5: 1), 6g was obtained as brown solid (20.6 mg, 39% isolated yield). m.p. = 168 – 170 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta \) 8.58 (d, \(J = 8.0 \text{Hz}, 1\H), 7.93 (d, \(J = 8.0 \text{ Hz}, 2\H), 7.42 – 7.29 (m, 4\H), 7.16 (d, \(J = 8.0 \text{ Hz}, 4\H), 4.29 (s, 2\H);

\(^{15}\) Zhi, Li.; Ringgenber, J. D.; Edwards, J. P.; Tegley, C. M.; West, S. J.; Pio, B.; Motamedi, M.; Jones, T. K.; Marschke, K. B.; Mais, D. E.; Schrader, W. T., Bioorg. Med. Chem. Lett., 2003, 13, 2075-2078.
$^{13}$C NMR (100 MHz, CDCl₃): $\delta$ 161.6, 150.4, 144.2, 129.0, 129.0, 125.1, 124.3, 124.0, 123.1, 122.0, 121.4, 118.9, 117.8. GCMS, m/z (% relative intensity, ion): 211[M⁺] (100), 183 (16), 154 (52), 127 (21), 102 (8), 91 (4), 77 (16). IR: $\tilde{\nu}$ = 3332, 1710, 1425, 1323, 1284, 1248, 867 (s).

**2,4-Dimethyl-5H-chromeno[3,4-c]pyridin-5-one (6h) [CAS: 104431-78-9]**

![Structure](image)

Compound 6h was prepared following the general procedure, starting from 2,6-dimethylnicotinic acid (37.8 mg, 0.25 mmol) and 2-iodophenol (82.5 mg, 0.375 mmol). After purification by column chromatography (ethyl acetate / hexane = 5: 1), 6h was obtained as a white solid (43.3 mg, 77% isolated yield). m.p. = 198–200 °C ¹H NMR (400 MHz, CDCl₃): $\delta$ 8.00 (d, $J$ = 8.0 Hz, 1H), 7.64 (s, 1H), 7.54 (t, $J$ = 8.0 Hz, 1H), 7.32 (t, $J$ = 8.0 Hz, 2H), 3.03 (s, 3H), 2.68 (s, 3H); $^{13}$C NMR (100 MHz, CDCl₃): $\delta$ 164.2, 162.5, 159.6, 152.6, 143.0, 132.4, 124.4, 123.5, 117.5, 116.2, 112.5, 26.7, 25.2. GCMS, m/z (% relative intensity, ion): 225[M⁺] (100), 197 (6), 156 (16), 127 (9), 115 (4), 102 (7), 77(4). IR: $\tilde{\nu}$ = 2924, 1720, 1589, 1250, 1189, 1051, 1024, 917
NMR Data

Ru-complex 8
3f
3n
3p
S48
3z

S60
4ba
4da
4fa
4ha
4ka
4la
6a
6b
6d
