Gold-Catalyzed Cascade Reactions of 4*H*-Furo[3,2-*b*]indoles with Allenamides: Synthesis of Indolin-3-one Derivatives

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ABSTRACT

Merging the ability of cationic gold(I) catalysts to activate unsaturated π-systems with the electrophiles driven ring-opening reactions of furans, we describe a new approach to 2-spiroindolin-3-ones from 4*H*-furo[3,2-*b*]indoles. The reaction occurs through a cascade sequence involving addition of a gold-activated allene to the furan moiety of the starting furoindole followed by a ring-opening/ring-closing event affording 2-spirocyclopentane-1,2-dihydro-3*H*-indolin-3-ones in moderate to good yields.

KEY WORDS

Gold catalysis, furoindoles, allenes, cascade reaction, 2-spiroindolin-3-ones.

INTRODUCTION

2-Spirocyclopentane-1,2-dihydro-3*H*-indol-3-ones (namely, spiropseudo-indoxyls) have been widely reported in the literature as core components of several indole alkaloids, such as aristotelone and brevianamide A, possessing interesting biological properties (Figure 1A).[1] More recently, the spiropseudo-indoxyl structure has been included in several simple molecules applicable as functional

fluorescent dyes[2] (Figure 1B) and identified as an intermediate useful for the chemical synthesis of minfiensine (Figure 1C).[3]

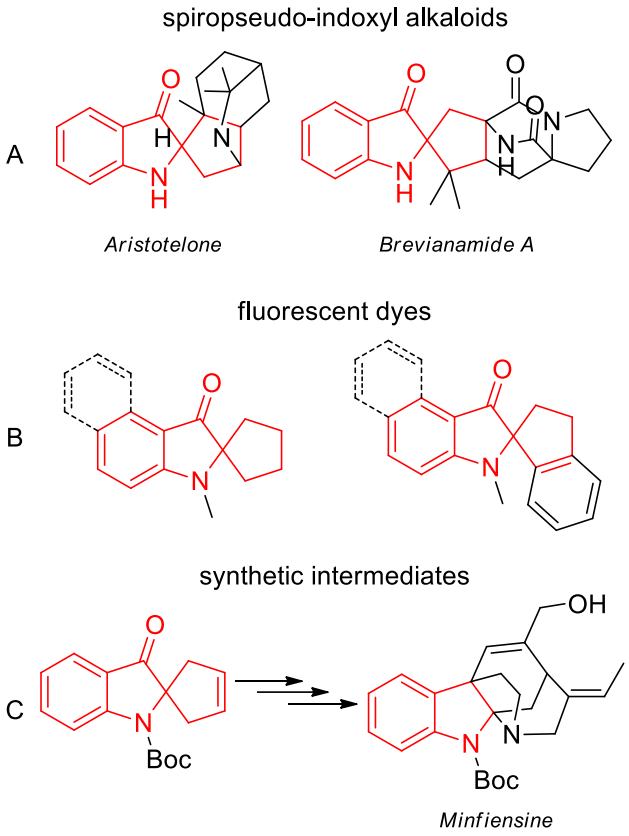
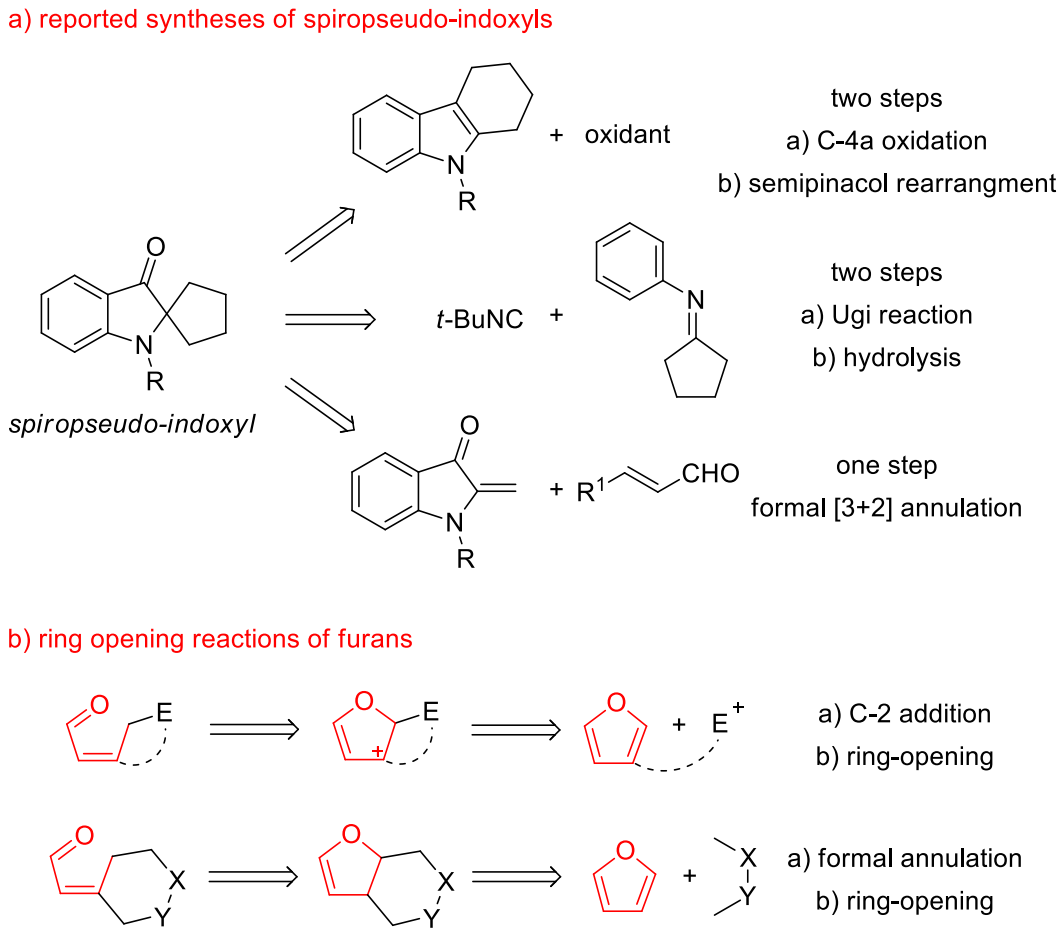


Figure 1. Representative spiropseudo-indoxyls: A natural compounds, B materials, C synthetic intermediate.

The most commonly applied methodology for the synthesis of the natural derivatives involves consecutive hydroxylation of tetrahydrocarbazoles followed by acid or base catalyzed semipinacol rearrangement of the corresponding α-hydroxyimine (Scheme 1a).[4] Over the years, the oxidation reaction conditions evolved from the use of *m*-CPBA[5] and molecular oxygen[6] to the use of biocatalytic transformations,[7] *N*-sulfonyloxaziridine-type oxidants[8] and photocatalytic aerobic oxidations.[9] Moreover, a powerful organocatalytic approach for the rearrangement step has been recently reported.[10] However, alternative synthetic strategies for the synthesis of spiropseudo-indoxyls are limited to an interrupted Ugi reaction between imines and isocyanides[11] (Scheme 1a) and to an enantioselective [3+2] annulation of α,β-unsaturated aldehydes with azaaurones (Scheme

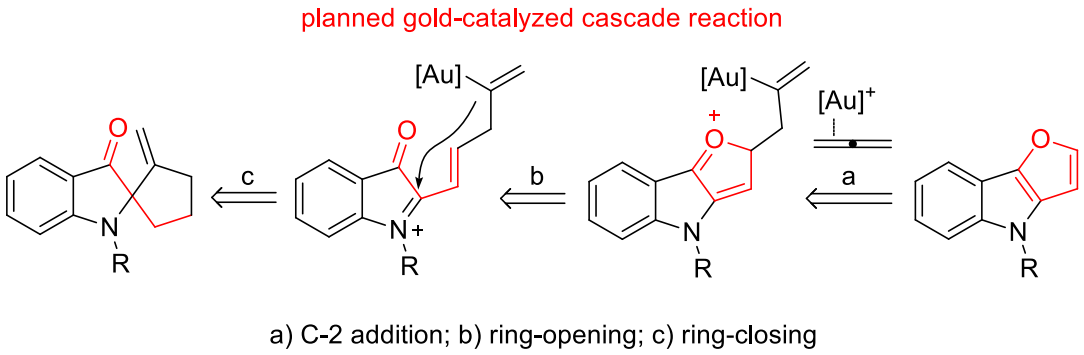
1a).[12] Furthermore, it is well recognized that ring opening reactions of furans allow for the installation of *carbonyl functionalities* often in a plain and selective manner (Scheme 1b).[13] Mostly, these reactions occur through a dearomatization step followed by a ring-opening event. Dearomatization can take advantage from the intra- or intermolecular addition of a suitable activated partner at C2 even if this position is already substituted.



Scheme 1. Reported syntheses of spirospeudo-indolyls (a) and ring opening reactions of furans (b)

Examples of this chemistry can be found in the intramolecular tropylium ion-mediated synthesis of naphth[1,2-*a*]azulenes,[13c] in the palladium-catalyzed route to α,β-unsaturated aldehydes,[13d] and in the intramolecular addition of imines,[13e] azides[13f] or σ-arylpalladium complexes[13g] for the synthesis of 2,3-disubstituted indoles. Moreover, [4+2][13h] and [5+2][13i] formal annulations/ring-opening reactions at C2-C3 of the furan ring afford carbonyl substituted isosaxoles or pyrazoles and aryl enones,

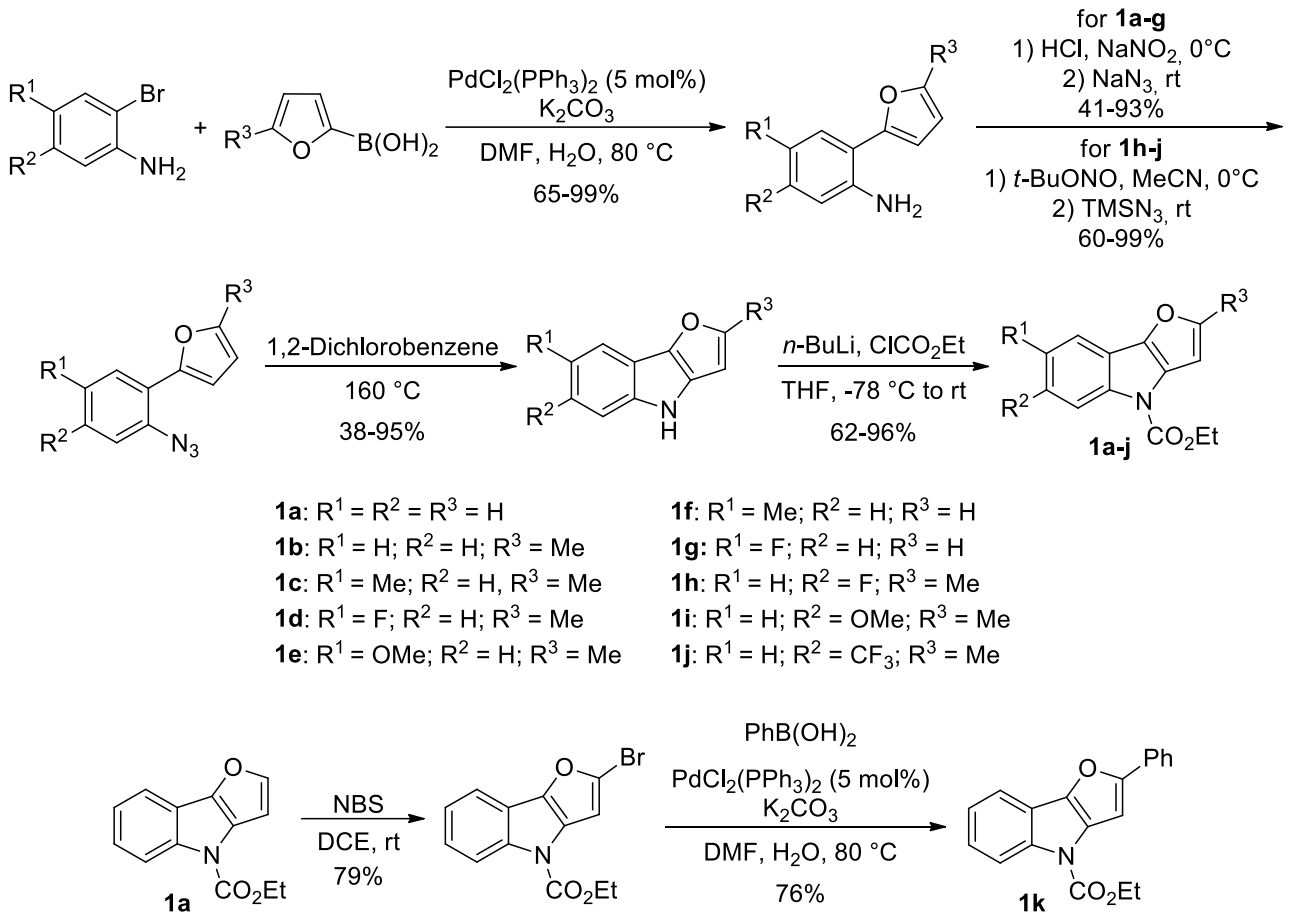
respectively. Taking into account these premises and our expertise in gold catalyzed reactions of 2-vinyl-indoles[14] and in gold catalyzed cascade reactions for the functionalization of the indole nucleus,[15] we planned to test the reactivity of 4*H*-furo[3,2-*b*]indoles in the presence of electrophilic gold(I) activate π-systems (allenamides) with the aim to develop a new cascade process encompassing functionalization at the furan moiety, possibly followed by a ring-opening/ring-closing event (Scheme 2). Gold(I) activated C3 unsubstituted allenamides react with nucleophilic partners (electron-rich arenes and heteroarenes) at the terminal carbon giving rise regioselectively to hydroarylated (enamide) derivatives.[16] In this paper we report a full account of the obtained results.



Scheme 2. Aim of our work

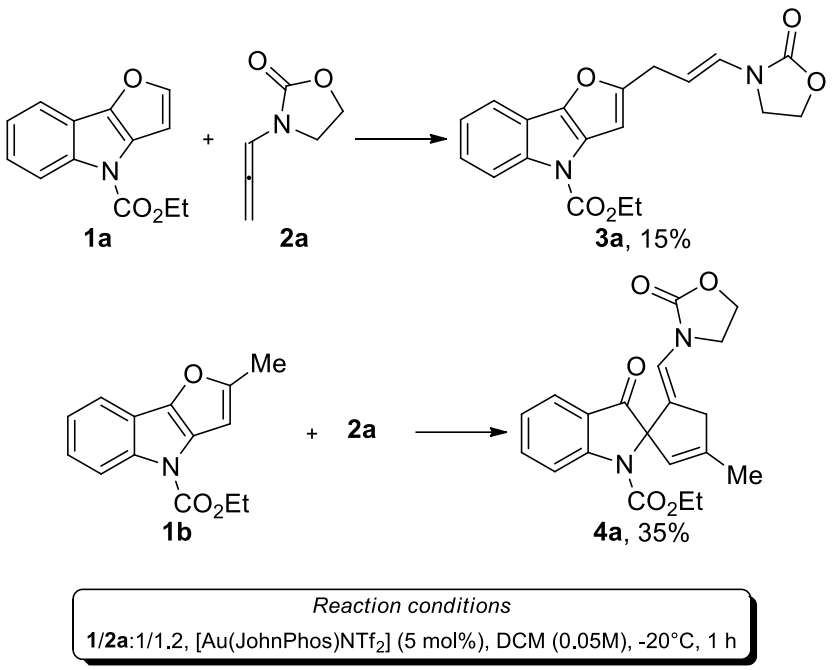
RESULTS AND DISCUSSION

There are only few reports on the synthesis of 4*H*-furo[3,2-*b*]indoles and, moreover, their reactivity is limited to simple *N*- or C2-functionalization reactions.[17] Therefore, we started our investigations with the synthesis of a small set of 4*H*-furo[3,2-*b*]indole-4-carboxylates (**1a-k**, Scheme 3). Compounds **1a-j**, bearing a hydrogen or a methyl group at C2, were synthesized in a four steps procedure by adaptation of reported methodologies (Scheme 3).[17] In the last step, *N*-4 was protected as carbamate in order to avoid the formation of undesired hydroamination side products in the reaction with activated allenamides.[16b,d] C2-Ph derivative **1k** was prepared from **1a** via bromination followed by Suzuki-Miyaura coupling with phenyl boronic acid. *N*-allenamides **2a-g**, employed in this work, are known compounds and were prepared according to literature procedures.[18]



Scheme 3. Synthesis of starting 4*H*-furo[3,2-*b*]indole-4-carboxylates **1a-k**

At the outset, furoindoles **1a** and **1b** were chosen as model compounds for the reactions with allenamide **2a** in the presence of preformed cationic complex [Au(JohnPhos)NTf_2] (Scheme 4). The reactions resulted in the isolation, in low yields, of simple hydroarylation product **3a** with furoindole **1a** and of 2-spirocyclopentane-indolin-3-one **4a** with furoindole **1b**.



Scheme 4. Gold-catalyzed reactions of furoindoles **1a-b** with allene **2a**: initial findings

Formation of compound **3a** was quite disappointing, although predictable. Instead, the formation of the spiro compound **4a** was remarkable as it involves the formation in a single step of a highly substituted 2-spiroindolin-3-one. The structures and the geometries around the double bonds of compounds **3a** and **4a** were assigned based on analytical and spectroscopic data and unambiguously confirmed by X-ray diffraction analysis of a single crystal (Figure 2).

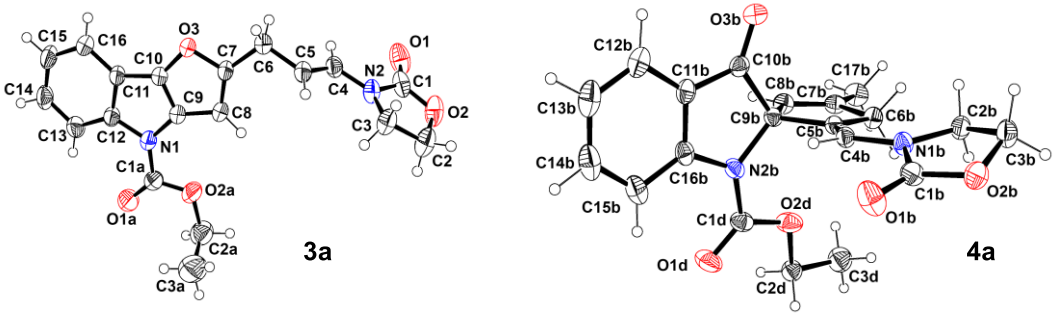


Figure 2. *Left*: ORTEPIII plot of compound **3a** showing the numbering schemes for all non-hydrogen atoms. Ellipsoids drawn at 50% probability. *Right*: ORTEPIII plot of compound **4a** showing the numbering schemes for all non-hydrogen atoms. Ellipsoids drawn at 50% probability. Only one of the two crystallographically independent, but conformationally equivalent molecules, is shown.

Therefore, we decided to look for the best reaction conditions for the synthesis of **4a** using **1b** and **2a** as model compounds (Scheme 4 and Table 1).

Table 1. Optimization of reaction conditions for the synthesis of **4a**

Entry	1b/2a	Catalyst, (5 mol%)	Solvent, [M]	T, °C	Time, min	4a[a], Yield%
1	1/1.2	[Au(JohnPhos)NTf_2]	DCM, 0.05 M	- 20	60	35%
2	1/1	[$(ArO)_3PAu(NTf)_2$]	DCM, 0.05 M	- 20	60	32%
3	1/1	[Au(IPr)NTf_2]	DCM, 0.05 M	- 20	180	57%
4	1/1	[Au(IPr)NTf_2]	Toluene, 0.05 M	- 20	180	n.r.[b]
5	**1/1.2**	**[Au(IPr)NTf_2]**	**DCM, 0.05 M**	**- 20**	**60**	**68%**
6	1/1.2	[Au(IPr)SbF_6]	DCM, 0.05 M	- 20	60	63%
7	1/1.2	$HNTF_2$ (20 mol%)	DCM, 0.05 M	- 20	60	n.r.[c]
8	1/1.5	$[Rh(cod)Cl]_2$	DCM, 0.05 M	- 20	24	n.r.[c]
9	1/1.5	$PtCl_2$	DCM, 0.05 M	- 20	24	n.r.[c]

All reactions were carried out using **1a** (0.2 mmol) and **2a** (0.2-0.24 mmol) in the stated solvent (0.05 M). [a] Isolated yield. [b] Complex mixture of unidentified products was observed besides starting materials. [c] Starting **1b** (and **2a**) was (were) recovered unreacted at the end of the reaction (see text).

Ar = 2,4-di-*t*-butylphenyl

IPr = Chloro[1,3-bis(2,6-diisopropylphenyl)imidazol-2-ylidene]

JohnPhos = (2-Biphenyl)di-*tert*-butylphosphine

Starting from the preliminary results obtained with [Au(JohnPhos)NTf_2] (Scheme 4 and Table 1, entry 1), we observed that the use of 5 mol% of [$(ArO)_3PAu(NTf)_2$] as catalyst did not produce any particular improvement in the yield (entry 2), while better results were obtained when [Au(IPr)NTf_2] was selected as reaction catalyst (entry 3). Therefore, the employment of a *N*-heterocyclic carbene-based gold(I) catalyst allowed for the isolation of **4a** in 57% after 3 hours. Varying the reaction medium from dichloromethane to toluene had a negative effect on the reaction outcome, since led to

complete degradation of starting materials without formation of the desired product (entry 4). Meanwhile, the use of a slight excess of *N*-allenamide **2a** led to improved 68% yield in shorter reaction time (entry 5). Finally, we checked the activity of [Au(IPr)SbF_6] in order to verify if the gold counterion could have any influence in the formation of the product (entry 6). However, **4a** was isolated in very similar 63% yield. In order to exclude an acid catalyzed process for the formation of **4a** we verified the activity of $HNTf_2$ under standard conditions. However, no product was identified besides unreacted **1b** (entry 7). Finally, the performances in this reaction of Rh(I)[19] and Pt(II)[20] catalysts were tested, (entries 8, 9) with no results. Indeed, both **1b** and **2a** were recovered unreacted at the end of the reactions.

Beside, we developed a catalytic system for the selective synthesis of **3a**, which is an unknown compound, obtained in the model reaction from **1b** and **2a** as single *E*-isomer (Scheme 4 and Table 2).

Table 2. Optimization of reaction conditions for the synthesis of **3a**

Entry	1b/2a	[Au]	Solvent, [M]	T, °C	Time, min	3a[a], Yield%
1	1/1.2	[Au(JohnPhos)NTf_2]	DCM, 0.05 M	- 20	60	15%
2	1/1.2	[Au(IPr)NTf_2]	DCM, 0.05 M	- 20	60	n.r.[b]
3	1/1	[$(ArO)_3PAuNTf_2$]	DCM, 0.05 M	- 20	60	75%
4	1.2/1	[$(ArO)_3PAuNTf_2$]	DCM, 0.05 M 4 Å MS	- 20	30	81%
5	**1.2/1**	**[$(ArO)_3PAuNTf_2$]**	**Toluene, 0.05 M** **4 Å MS**	**- 20**	**15**	**90%**
6	1.2/1	$HNTf_2$ (20 mol%)	Toluene, 0.05 M 4 Å MS	- 20	15	n.r.[b]

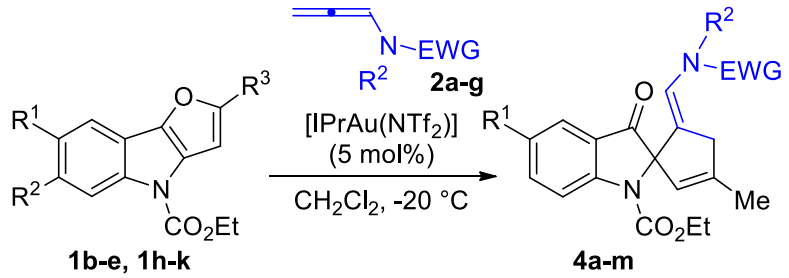
All reactions were carried out using **1a** (0.2-0.24 mmol) and **2a** (0.2-0.24 mmol) in the stated solvent (0.05 M). [a] Isolated yield. [b] Complex mixture of unidentified products was observed besides starting materials.

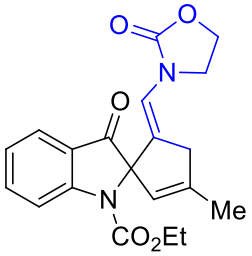
Ar = 2,4-di-*t*-butylphenyl.

IPr = Chloro[1,3-bis(2,6-diisopropylphenyl)imidazol-2-ylidene].

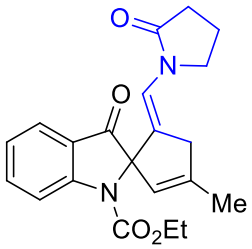
JohnPhos = (2-Biphenyl)di-*tert*-butylphosphine.

In the first attempt, **3a** was obtained in poor 15% yield (Scheme 4 and Table 2, entry 1). Moreover, applying the best reaction conditions for the synthesis of **4a**, worse results were obtained (entry 2). Therefore, we observed that the formation of **3a** from **1a** was promoted by the use of an electrophilic triarylphosphite-based gold(I) catalyst, that yielded **3a** in 75% as single *E* isomer (entry 3). Final optimization of the reaction conditions was achieved using 4Å molecular sieves in the presence of a slight excess of furoindole **1a** (entry 4) and switching to toluene as solvent (entry 5). Under these optimized reaction conditions, **3a** was obtained in excellent 90% yield. Also in this case an acid-promoted process could be excluded (entry 6). With the optimized reaction conditions in hand, we first evaluated the reaction scope for the synthesis of 2-spirocyclopentane-indol-3-ones **4** considering the novelty of the transformation and the structure of the obtained compounds (Scheme 5).

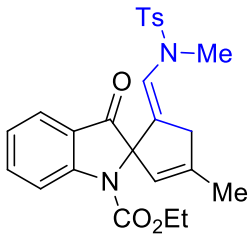




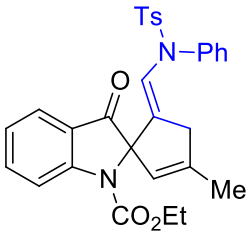
4a, 68%



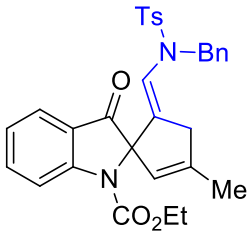
4b, 61[b]



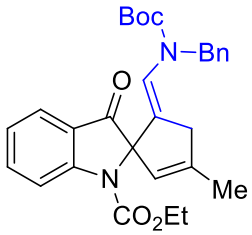
4c, 77%



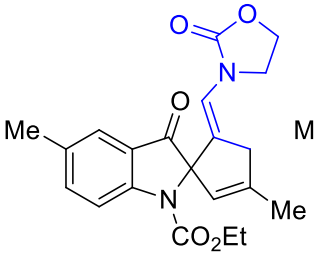
4d, 49%



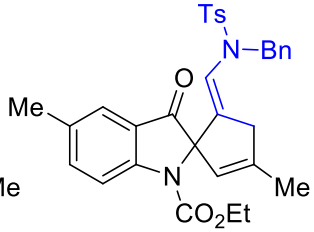
4e, 62%



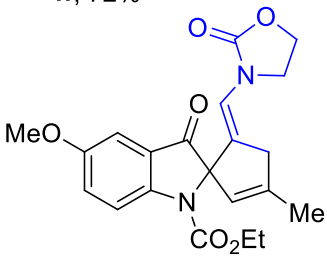
4f, 72%[c]



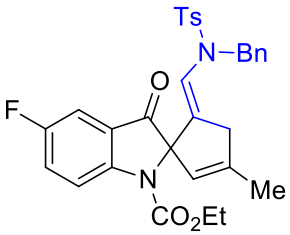
4g, 56%[b]



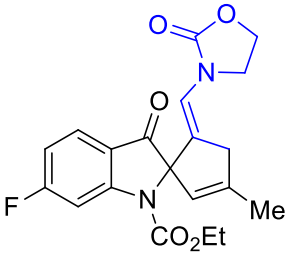
4h, 60%[b,d]



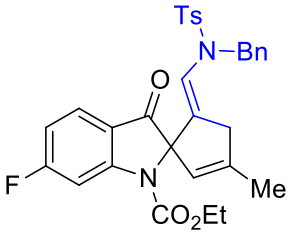
4i, 44%[b]



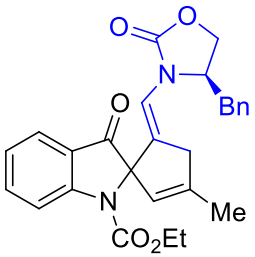
4j, 45%[b]



4k, 52%[b]



4l, 65%[b]



4m, 49%[b]

[a] Reaction conditions: **1** (0.2 mmol), **2** (0.24 mmol), [Au(IPr)NTf$_2$] (5 mol%) in CH_2Cl_2 (0.05 M), -20 °C, 1-18 h. Isolated yields. [b] 1.5 eq. of **2** were used. [c] 2.0 eq. of **2** were used. [d] Slow addition.

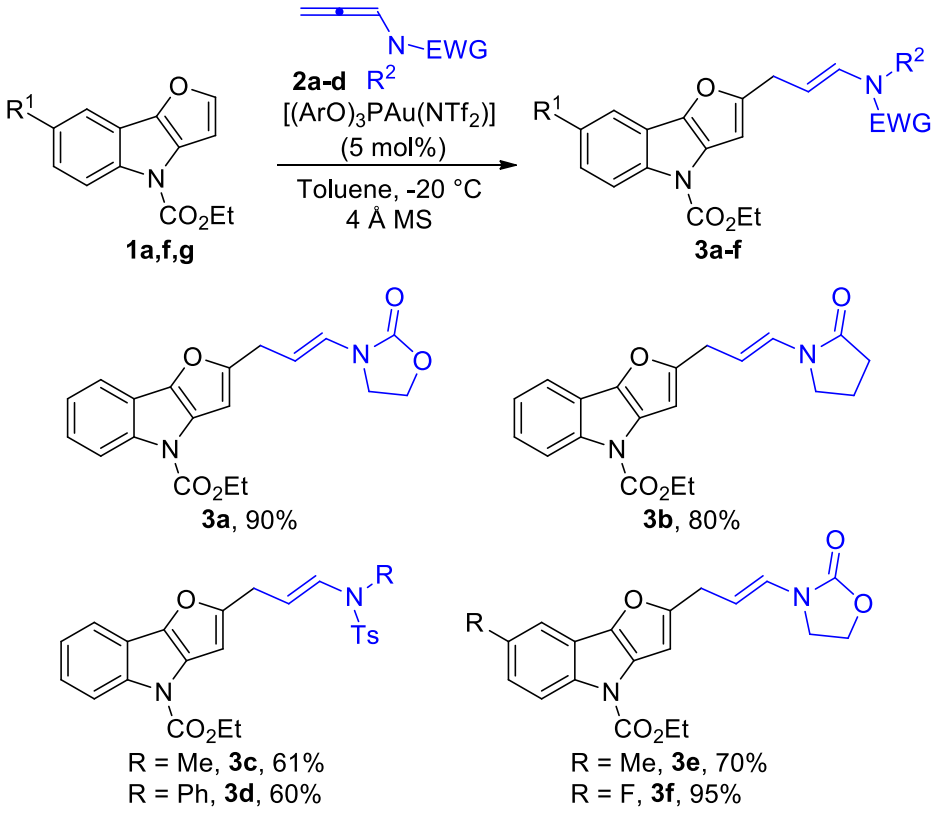
IPr = 1,3-bis(2,6-diisopropylphenyl)imidazole-2-ylidene.

Scheme 5. Synthetized 2-spirocyclopentane-indol-3-ones **4a-m**.[a]

At the outset, we tested the reactivity of **1a** with different allenamides **2a-f**. The reaction proceeded with moderate yield when pyrrolidone *N*-allenamide **2b** was employed, affording **4b** in 61% yield. Other *N*-allenamides, bearing an electronwithdrawing tosyl group at nitrogen, were also tested. In the case of *N*,4-dimethyl-*N*-(2λ^5-propa-1,2-dien-1-yl)benzenesulfonamide (**2c**), we were able to isolate the corresponding product **4c** in satisfactory 77% yield, while the reaction with the corresponding *N*-phenyl substituted *N*-allenamide **2d** was less effective and product **4d** was isolated in 49% yield together with unreacted indole and unidentified side-products. *N*-benzylated allenamides were also employed. In particular *N*-benzyl-*N*-tosyl allenamide **2e** reacted with **1b** affording **4e** in 62% yield, while the modification of the electronwithdrawing group from tosyl to *t*-butoxycarbonyl (*Boc*, allene **2f**) led to the formation of **4f** in 72% yield. The use of furoindoles other than **1b** was next evaluated. Thus, the reaction scope with furoindoles **1c-e**, **1h-j** was evaluated using oxazolidinone- and *N*-tosyl-*N*-benzyl allenamides **2a** and **2e**, being the latter more reactive than the former. In particular, ethyl 2,7-dimethyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1c**, bearing a weak ED group at C7, smoothly reacted with allenamides **2a** and **2e**, giving the corresponding products **4g** and **4h** in 56% and 60% yield , respectively. Moreover, a similar behavior was observed with furoindole **1e**, bearing a stronger ED methoxy group at C7, giving rise with allenamide **2a** to spiroindolinone **4i** in moderate 44% yield. However, when the same substituent was shifted from C7 to C6 on the starting furoindole (**1i**), both reactions with allenamides **2a** and **2e** failed. The influence of EWD groups was next tested. Thus, furoindole **1d** bearing at C7 a fluorine atom did not react with allenamide **2a**, whereas in the presence of allenamide **2e**, spiroindole **4j** was isolated in moderate 45%. Moving the fluorine atom from C7 to C6 on the starting furoindole (**1h**), we observed an increase in the reactivity and the reactions with both allenamides **2a** and **2e** afforded the corresponding spiroindolinones **4k** and **4l** in 52 and 65% yield. These results demonstrated that substituents with opposite EWD/ED properties exert opposite

effects on the reaction outcome and on the reactivity of C2 towards electrophilic reagents. Unfortunately, the presence of a strong EWD group such as a trifluoromethyl group on the starting furoindole (**1j**) totally inhibits the reactivity towards both allenamides **2a** and **2e**. Moreover, any attempt to react C2 phenyl substituted furoindole **1k** with allenamides failed and starting materials were recovered unreacted even after prolonged reaction time at room temperature. Finally, furoindole **1a** was tested in the reaction with enantiopure allenamide **2g** bearing a benzyl group on the oxazolidinone moiety ((*R*)-4-benzyl-3-(propa-1,2-dien-1-yl)oxazolidin-2-one). The reaction resulted in the isolation of **4m** as a pair of diastereoisomers (13:1) in 49% yield. The structure of the prevailing compound **4m** was demonstrated via mono and bidimensional NMR analyses.

Subsequently, we briefly explored the scope for the synthesis of 2-amidoallyl-4*H*-furo[3,2-*b*]indoles **3** (Scheme 6).

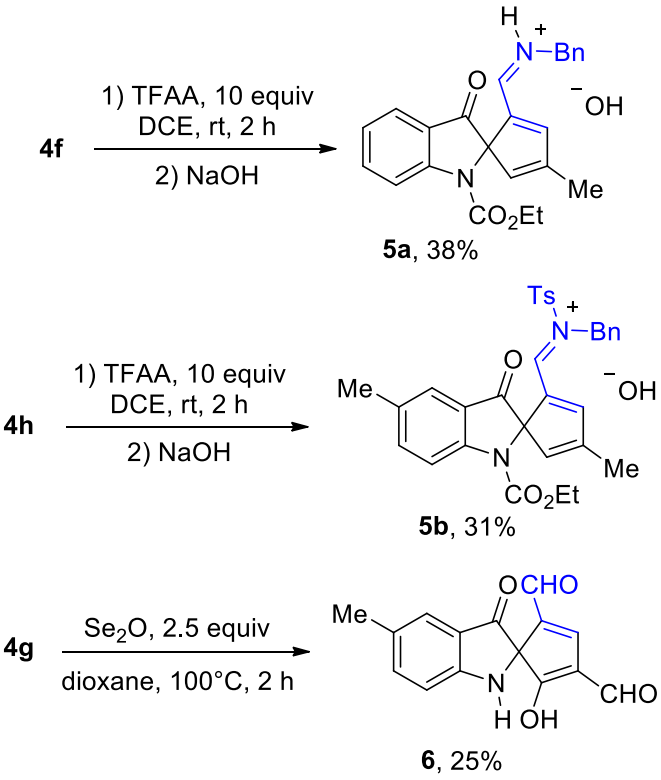


[a]*Reaction conditions:* **1** (0.24 mmol), **2** (0.2 mmol), [(ArO)$_3$PAuNTf$_2$] (5 mol%) in toluene (0.05 M), 4 Å MS, -20 °C, 15 min. Isolated yields. Ar = 2,4-di-*t*-butylbenzene.

Scheme 6. Synthesized 2-amidoallyl-4*H*-furo[3,2-*b*]indoles **3a-f**.[a]

In this case, pyrrolidone-derived *N*-allenamide **2b** led to the formation of **3b** in 80% yield, while hydroarylated derivatives **3c** and **3d** were efficiently obtained by the employment of *N*-tosylated *N*-allenamides **2c** and **2d**. We also extended the scope to different 4*H*-furo[3,2-*b*]indoles bearing a methyl group or a fluorine atom in *7*-position with **2a**. These modifications were well tolerated and compound **3e** and **3f** were isolated in 70% and 95% yield, respectively.

Then, we planned to carry out some simple synthetic elaborations on the obtained spiro-compounds **4**, scheme 7. Compounds **4** demonstrated to be stable under both chemical ($NaBH_4$, $LiAlH_4$) and catalytic reductive conditions (H_2 - Pd/C; H_2 - Pt_2O). The same was observed under basic hydrolytic conditions. However, treatment of **4f** and **4h** with trifluoroacetic acid followed by basic work-up, resulted in the isolation of ammonium salts **5a** and **5b** albeit in poor yields beside a series of unidentified by-products. Finally, under oxidative conditions (Se_2O) we were able to isolate compound **6** resulting from an extensive oxidation process in 25% yield. Also in this reaction the main compound was accompanied by several unidentified by-products.



Scheme 7. Synthetic elaborations of compounds **4**

Finally, we believe that the reaction occurs in both cases through the activation of the *N*-allenamide by means of the cationic gold(I) species (Scheme 8, intermediate **I**), followed by nucleophilic addition of the C-2 furan. Next, when R = H (**1a**) the reaction proceeds by a well-known hydroarylation mechanism[16] via proton elimination and cleavage of the gold-carbon bond by the proton generated in the previous step (protodeauration), delivering furoindole **3** (*path A*). When R = Me (**1b**), intermediate **II** cannot re-aromatize and undergoes a rearrangement involving a furan ring opening event[13] with formation of iminium indole derivative **III**. Subsequently, cyclization of **III** may be initiated by enaminone system providing intermediate **IV** or assisted by gold via an electrostatic interaction with indole C2 resulting in the pseudo-metallacyclic intermediate **V**. In both cases, elimination of gold(I) affords the final reaction product **4** (*path B*).

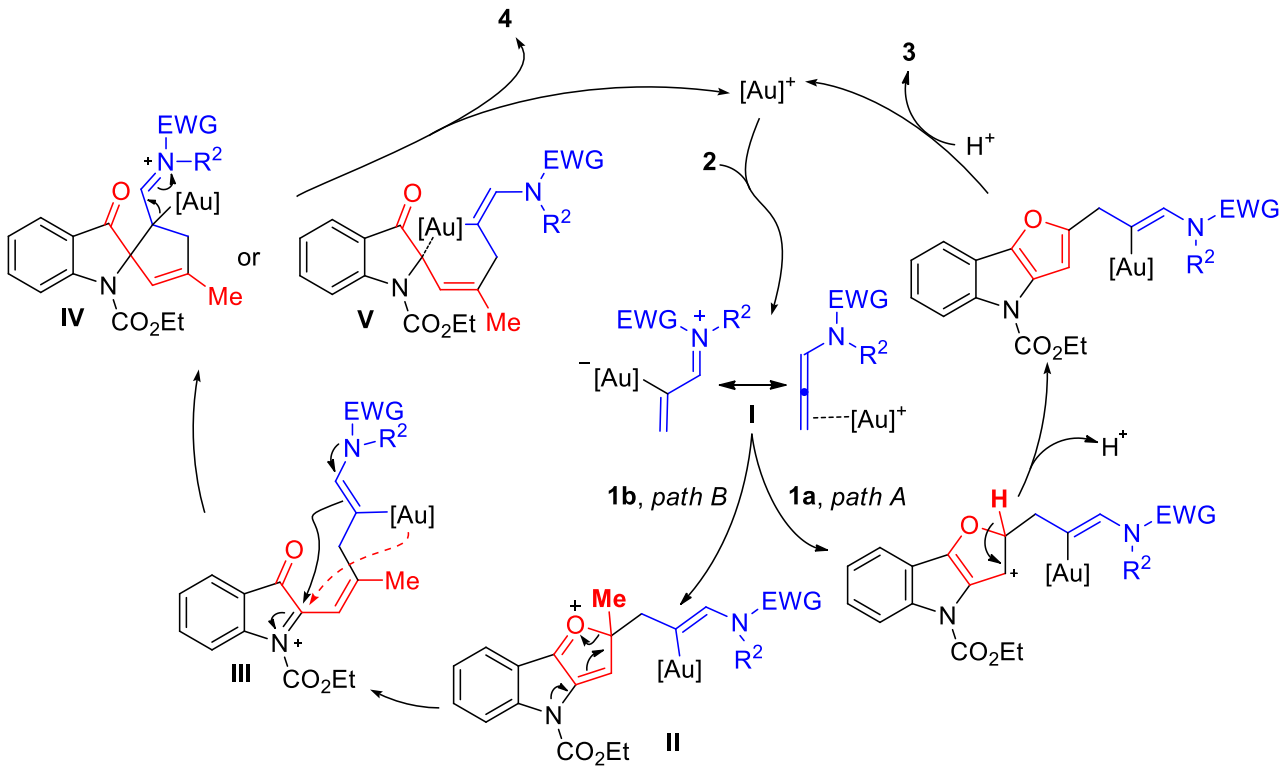
The allene is activated by coordination

to cationic gold and undergoes electrophilic aromatic substitution with the electron-rich arene to give vinyl-gold

complex B, which is deprotonated to produce the neutral

vinyl-gold intermediate C. Cleavage of the gold-carbon bond by the proton generated in the previous step affords 2

and regenerates the cationic gold catalyst



Scheme 8. Proposed reaction mechanism

Although we have no evidences of the subsistence of intermediates **IV** and **V** we believe, in accordance with several authors,[20,21] that an intermediate like **V** better explains the stereochemistry of the obtained products. The role of allenamides in these reactions could be related to the formation of stabilized reaction intermediates upon activation by gold, see intermediate **I** in scheme 8.[20, 22]

CONCLUSIONS

In summary, we designed a novel strategy for the synthesis of indolin-3-one derivatives. The idea was to bring together the ring opening reactions of furan derivatives, promoted by electrophiles, with the construction of indolin-3-one scaffolds in which the carbonyl group arises from the ring opening reaction of the furan ring condensed with the starting indole skeleton. The chosen electrophiles are gold(I) activated allenamides which react with 2-methyl-4*H*-furo[3,2-*b*]indoles in a cascade reaction involving C2 hydroarylation, furan ring opening and intramolecular spirocyclisation giving rise to 2-spiroindolin-3-ones in moderate to good yields. Moreover, variation of the electronic properties of furoindoles revealed an interesting mechanism of modulation for the reactivity at C2. The limit of

this approach resides in the need to operate with C2 substituted furoindoles in order to avoid the competitive hydroarylation and rearomatisation sequence. Furthermore, only C2 alkyl-substituted furoindoles participate in these reactions and the reaction performed with C2 phenyl-substituted furoindole failed to give the expected compound. Despite that, we believe we have shaped the right conditions for the growth of a new synthetic concept that, if properly developed, could give rise to diverse and nice results. Thus, switching to different electrophiles or involving the C2-C3 bond in addition/annulation reactions followed by new rearrangements will be the subject of our next investigations.

EXPERIMENTAL SECTION

All chemicals and solvents are commercially available and were used after distillation or treatment with drying agents. Silica gel F254 thin-layer plates were employed for thin-layer chromatography (TLC). Silica gel 40-63 micron/60 Å was employed for flash column chromatography. Melting points were measured with a Perkin- Elmer DSC 6 calorimeter at a heating rate of 5 °C/min and are uncorrected. ^{1}H and ^{13}C NMR spectra were determined with a Varian-Gemini 300, Bruker 300, Bruker 500 or Bruker 600 spectrometers at room temperature in $CDCl_3$, CD_2Cl_2 or C_6H_6 with residual solvent peaks as the internal reference. The APT sequences were used to distinguish the methine and methyl carbon signals from those arising from methylene and quaternary carbon atoms. Two-dimensional NMR experiments were performed, where appropriate, to aid the assignment of structures. Low-resolution MS spectra were recorded with a Thermo-Finnigan LCQ advantage AP electrospray/ion trap equipped instrument using a syringe pump device to directly inject sample solutions. Slow additions were performed using NE-1000 Programmable Single Syringe Pump of the New Era Pump Systems Inc. *N*-allenamides **2a-g** are known compounds and were prepared according to literature procedures.[18] PPh_3PAuCl, $AuCl_3$, $AgNTf_2$ and $AgSbF_6$ were purchased from commercial suppliers and used as received, while the rest of the gold catalysts were prepared following literature procedures.[23]

General procedures for the synthesis of ethyl 4*H*-furo[3,2-*b*]indole-4-carboxylates 1a-j.

According to the reaction sequence reported in Scheme 3, 4*H*-furo[3,2-*b*]indole-4-carboxylates **1a-f** were synthesized in a four steps procedure according to the ensuing general procedures.

Step 1. To a N_2-flushed solution of furan-2-ylboronic acid (1.5 equiv.), potassium carbonate (4.0 equiv.), $PdCl_2(PPh_3)_2$ (5 mol%) in DMF and water (4.4:1), 2-bromoaniline (1.0 equiv.) was added. The reaction mixture was heated at reflux for 3 h and then cooled at room temperature. The mixture was diluted with water and extracted with ethyl acetate. The organic layer was washed with brine, dried over Na_2SO_4, filtered and the solvent concentrated under vacuum. The crude was purified by flash column chromatography to yield the corresponding 2-(furan-2-yl)aniline.

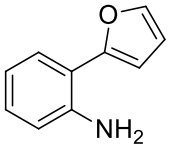
Step 2 (method A). To a solution of 2-(furan-2-yl)aniline (1.0 equiv.), an aqueous solution of hydrochloric acid (15%.) was added dropwise at 0° C. Then a solution of sodium nitrite (1.2 equiv.) in water was added dropwise. The mixture was stirred for 1 h at 0° C. Then a solution of sodium azide (2.4 equiv.) in water was added dropwise at 0° C and the mixture was stirred for 1 h at room temperature. The mixture was diluted with water, extracted with ethyl acetate, washed with sodium bicarbonate saturated solution and brine. The organic layer was dried over Na_2SO_4 and concentrated. The crude was purified by flash column chromatography to yield the corresponding 2-(2-azidophenyl)furan.

Step 2 (method B). To a solution of 2-(furan-2-yl)aniline (1.0 equiv.) in CH_3CN (0.5 M) at 0° C *t*-BuONO (1.2 equiv.) was added, followed by $TMSN_3$ (1.2 equiv.) dropwise. The resulting solution was stirred at room temperature for 1 h and then was concentrated in vacuum. Purification by flash column chromatography yielded the corresponding 2-(2-azidophenyl)furan.

Step 3. To a solution of 1,2-dichlorobenzene (final concentration 0.5 M) heated at 160° C, 2-(2-azidophenyl)furan (1.0 equiv.) was added dropwise. The reaction mixture was stirred for 3 h. Then solvent was concentrated under vacuum. The crude was purified by flash column chromatography to yield the corresponding 4*H*-furo[3,2-*b*]indole.

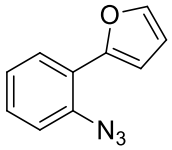
Step 4. To a N_2-flushed solution of appropriate 4*H*-furo[3,2-*b*]indole (1.0 equiv.) in THF (0.1 M), a solution of *n*-butyllithium (1.6 M in hexane, 1.1 equiv.) was added dropwise at -78° C. The reaction mixture was stirred for 30 minutes. Ethyl chloroformate (1.5 equiv.) was added dropwise and the reaction was brought to room temperature and stirred for 2 h before of being quenched with ammonium chloride saturated solution. The organic layer was extracted with ethyl acetate, dried over Na_2SO_4, filtered and the solvent concentrated under vacuum. The crude was purified by flash column chromatography to yield the corresponding ethyl 4*H*-furo[3,2-*b*]indole-4-carboxylate.

2-(furan-2-yl)aniline General procedure was followed using furan-2-ylboronic acid (487 mg, 4.35



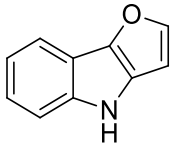
mmol), potassium carbonate (1.60 g, 11.6 mmol), $PdCl_2(PPh_3)_2$ (102 mg, 0.145 mmol), 2-bromoaniline (500 mg, 2.9 mmol) in DMF (13 mL) and water (3 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 95:5), yielded 2-(furan-2-yl)aniline (344 mg, 98%) as brownish oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.54 - 7.43 (m, 2H), 7.11 (m, 1H), 6.83 - 6.69 (m, 2H), 6.58 (d, J = 3.4 Hz, 1H), 6.51 (dd, J = 3.3, 1.9 Hz, 1H), 4.35 (s, 2H). Data are in agreement with those reported in literature.[17]

2-(2-azidophenyl)furan General procedure (method A) was followed using 2-(furan-2-yl)aniline



(1.55 g, 9.76 mmol), a solution of HCl (1.96 mL, 64.42 mmol) in water (9 mL), a solution of sodium nitrite (1.62 g, 23.42 mmol) in water (7.6 mL), a solution of sodium azide (1.52 g, 23.42 mmol) in water (12.4 mL). Purification by flash column chromatography (SiO_2, hexane 100%), yielded 2-(2-azidophenyl)furan (1.68 g, 93%) as brownish oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.85 (d, J = 7.7 Hz, 1H), 7.48 (s, 1H), 7.45 - 7.12 (m, 3H), 7.08 (d, J = 3.2 Hz, 1H), 6.51 (s, 1H). Data are in agreement with those reported in literature.[17]

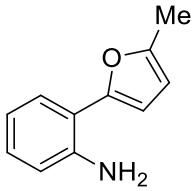
4H-furo[3,2-b]indole General procedure was followed using 1,2-dichlorobenzene (14.5 mL), 2-(2-



azidophenyl)furan (1.63 g, 8.81 mmol). Purification by flash column chromatography (SiO_2, hexane 100%), yielded 4*H*-furo[3,2-*b*]indole (1.02 g, 73%) as reddish oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.71 (m, 1H), 7.55 (d, J = 2.0 Hz, 1H), 7.40 (m, 1H), 7.26 - 7.07 (m, 2H), 6.59 (d, J = 2.0 Hz, 1H), 5.30 (s, 1H). Data are in agreement with those reported in literature.[17]

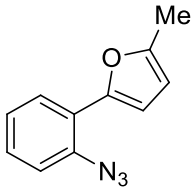
Ethyl 4H-furo[3,2-b]indole-4-carboxylate (**1a**). General procedure was followed using 4*H*-furo[3,2-*b*]indole (250 mg, 1.6 mmol), *n*-butyllithium (1.6 M in hexane, 1.1 mL, 1.76 mmol), ethyl chloroformate (230 μL, 2.4 mmol) in THF (16 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 95:5), yielded **1a** (277 mg, 75%) as orange solid (m.p. 60-61.9° C). ^{1}H NMR (300 MHz, $CDCl_3$): 8.34 (bs, 1H), 7.67 (m, 1H), 7.54 (d, *J* = 2.0 Hz, 1H), 7.35 - 7.25 (m, 2H), 6.82 (bs, 1H), 4.52 (q, *J* = 7.1 Hz, 2H), 1.51 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 151.1 (C), 145.8 (CH), 143.5 (C), 138.8 (C), 129.5 (C), 124.0 (CH), 123.4 (CH), 118.1 (C), 116.4 (CH), 116.4 (CH), 103.1 (CH), 63.0 (CH_2), 14.5 (CH_3). EI-MS: m/z(%) = 229 (100) $[M]^+$. Anal. Calcd for $C_{13}H_{11}NO_3$: C, 68.11; H, 4.84; N, 6.11. Found: C, 67.99; H, 4.83; N, 6.12.

2-(5-methylfuran-2-yl)aniline General procedure was followed using (5-methylfuran-2-yl)boronic



acid (548 mg, 4.35mmol), potassium carbonate (1.60 g, 11.6 mmol), $PdCl_2(PPh_3)_2$ (102 mg, 0.145 mmol), 2-bromoaniline (500 mg, 2.9 mmol) in DMF (13 mL) and water (3 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 9:1), yielded 2-(5-methylfuran-2-yl)aniline (480 mg, 95%) as brownish oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.46 (dd, *J* = 7.7, 1.3 Hz, 1H), 7.09 (ddd, *J* = 8.0, 7.3, 1.6 Hz, 1H), 6.85 - 6.68 (m, 2H), 6.47 (d, *J* = 3.2 Hz, 1H), 6.10 (m, 1H), 4.44 (d, *J* = 0.7 Hz, 2H), 2.38 (s, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 151.6 (C), 151.1 (C), 143.0 (C), 128.2 (CH), 127.2 (CH), 118.4 (CH), 116.60 (C), 116.58 (CH), 107.4 (CH), 107.3 (CH), 13.7 (CH_3). ESI(+)-MS: m/z(%) = 174 (100) $[M+H]^+$. Anal. Calcd for $C_{11}H_{11}NO$: C, 76.28; H, 6.40; N, 8.09. Found: C, 76.35; H, 6.39; N, 8.10.

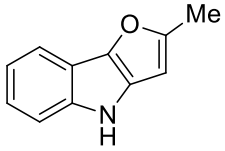
2-(2-azidophenyl)-5-methylfuran General procedure (method A) was followed using 2-(furan-2-yl)-



4-methylaniline (2.14 g, 12.4 mmol), HCl (15%, 12.4 mL), a solution of sodium nitrite (1.03 g, 14.88 mmol) in water (31 mL), a solution of sodium azide (1.31 g, 20.2 mmol) in water (4.7 mL). Purification by flash column chromatography (SiO_2, hexane 100%), yielded 2-(2-azidophenyl)-5-methylfuran (1.71 g, 69%) as yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.84 (dd, *J* = 7.7, 1.2 Hz, 1H), 7.30 - 7.11 (m, 3H), 6.98 (d, *J* = 3.2 Hz, 1H), 6.09 (m, 1H), 2.39 (s, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 152.2 (C), 148.3 (C), 134.9 (C), 127.8 (CH),

126.7 (CH), 125.3 (CH), 123.1 (C), 119.2 (CH), 111.9 (CH), 108.3 (CH), 14.1 (CH_3). Anal. Calcd for $C_{11}H_9N_3O$: C, 66.32; H, 4.55; N, 21.09. Found: C, 66.36; H, 4.54; N, 21.11.

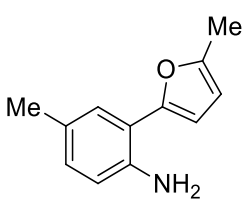
2-methyl-4H-furo[3,2-b]indole. General procedure was followed using 1,2-dichlorobenzene (3.2



mL), 2-(2-azidophenyl)-5-methylfuran (400 mg, 2 mmol). Purification by flash column chromatography (SiO_2, hexane 100% to hexane/ethyl acetate 95:5), yielded 2-methyl-4*H*-furo[3,2-*b*]indole (269 mg, 79%) as reddish oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.68 (m, 1H), 7.55 (bs, 1H), 7.37 (m, 1H), 7.18 - 7.08 (m, 2H), 6.21 (d, J = 1.0 Hz, 1H), 2.50 (d, J = 1.0 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 156.1 (C), 140.7 (C), 139.0 (C), 131.0 (C), 120.8 (CH), 119.7 (CH), 115.5 (CH), 114.8 (C), 112.0 (CH), 95.8 (CH), 14.9 (CH_3). ESI(+)-MS: m/z(%) = 172 (100) $[M+H]^+$. Anal. Calcd for $C_{11}H_9NO$: C, 77.17; H, 5.30; N, 8.18. Found: C, 77.26; H, 5.29; N, 8.17.

*Ethyl 2-methyl-4H-furo[3,2-b]indole-4-carboxylate (**1b**).* General procedure was followed using 2-methyl-4*H*-furo[3,2-*b*]indole (107 mg, 0.63 mmol), *n*-butyllithium (1.6 M in hexane, 430 µL, 0.69 mmol), ethyl chloroformate (90 µL, 0.95 mmol) in THF (6.2 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 95:5), yielded **1b** (122 mg, 79%) as orange solid (m.p. 107.1-108.2° C). ^{1}H NMR (300 MHz, $CDCl_3$): 8.30 (s, 1H), 7.59 (m, 1H), 7.32 - 7.19 (m, 2H), 6.44 (s, 1H), 4.50 (q, J = 7.1 Hz, 2H), 2.49 (d, J = 0.8 Hz, 3H), 1.49 (t, J = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 156.2 (C), 151.2 (C), 141.7 (C), 137.9 (C), 130.3 (C), 123.2 (CH), 123.1 (CH), 118.3 (C), 116.2 (CH), 115.6 (CH), 99.4 (CH), 62.9 (CH_2), 14.7 (CH_3), 14.4 (CH_3). ESI(+)-MS: m/z(%) = 244 (100) $[M+H]^+$. Anal. Calcd for $C_{14}H_{13}NO_3$: C, 69.12; H, 5.39; N, 5.76. Found: C, 68.97; H, 5.40; N, 5.75.

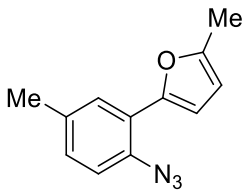
4-methyl-2-(5-methylfuran-2-yl)aniline. General procedure was followed using (5-methylfuran-2-



yl)boronic acid (1.89 g, 15 mmol), potassium carbonate (5.50 g, 40 mmol), $PdCl_2(PPh_3)_2$ (350 mg, 0.5 mmol), 2-bromo-4-methylaniline (1.86 g, 10 mmol) in DMF (45 mL) and water (10 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 95:5), yielded 4-methyl-2-(5-methylfuran-2-yl)aniline

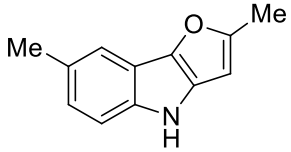
(1.26 g, 65%) as orange oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.32 (m, 1H), 6.93 (dd, *J* = 7.9, 1.7 Hz, 1H), 6.68 (d, *J* = 8.1 Hz, 1H), 6.48 (d, *J* = 3.2 Hz, 1H), 6.13 (m, 1H), 4.08 (bs, 2H), 2.40 (s, 3H), 2.30 (s, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 151.6 (C), 151.0 (C), 140.4 (C), 129.0 (CH), 127.7 (C), 127.4 (CH), 116.8 (CH), 116.6 (C), 107.4 (CH), 107.3 (CH), 20.5 (CH_3), 13.7 (CH_3). ESI(+)-MS: m/z(%) = 188 (100) $[M+H]^+$. Anal. Calcd for $C_{12}H_{13}NO$: C, 76.98; H, 7.00; N, 7.48. Found: C, 76.83; H, 6.99; N, 7,47.

2-(2-azido-5-methylphenyl)-5-methylfuran. General procedure (method A) was followed using 4-



methyl-2-(5-methylfuran-2-yl)aniline (1.22 g, 6.5 mmol), HCl (15%, 6.5 mL), a solution of sodium nitrite (538 mg, 7.8 mmol) in water (16 mL), a solution of sodium azide (689 mg, 10.6 mmol) in water (2.4 mL). Purification by flash column chromatography (SiO_2, hexane 100%), yielded 2-(2-azido-5-methylphenyl)-5-methylfuran (1.06 g, 77%) as orange oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.63 (m, 1H), 7.14 - 7.03 (m, 2H), 6.94 (d, *J* = 3.3 Hz, 1H), 6.09 (m, 1H), 2.38 (m, 3H), 2.37 (s, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 151.6 (C), 148.1 (C), 134.5 (C), 131.9 (C), 128.2 (CH), 126.8 (CH), 122.5 (C), 118.7 (CH), 111.4 (CH), 107.9 (CH), 20.9 (CH_3), 13.6 (CH_3). Anal. Calcd for $C_{12}H_{11}N_3O$: C, 67.59; H, 5.20; N, 19.71. Found: C, 67.45; H, 5.19; N, 19.74.

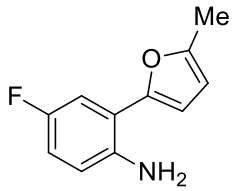
2,7-dimethyl-4H-furo[3,2-b]indole. General procedure was followed using 1,2-dichlorobenzene (8.5



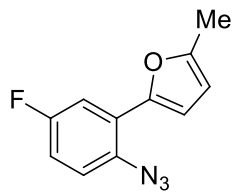
mL), 2-(2-azido-5-methylphenyl)-5-methylfuran (1.02 g, 4.81 mmol). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 95:5), yielded 2,7-dimethyl-4*H*-furo[3,2-*b*]indole (0.56 g, 63%) as reddish waxy solid. ^{1}H NMR (300 MHz, $CDCl_3$): 7.54 - 7.29 (m, 2H), 7.27 (d, *J* = 8.5 Hz, 1H), 6.99 (dd, *J* = 8.3, 1.2 Hz, 1H), 6.21 (d, *J* = 0.9 Hz, 1H), 2.52 (d, *J* = 0.9 Hz, 3H), 2.50 (s, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 155.9 (C), 140.5 (C), 137.4 (C), 131.3 (C), 129.1 (C), 122.2 (CH), 115.4 (CH), 114.9 (C), 111.7 (CH), 95.9 (CH), 21.5 (CH_3), 15.0 (CH_3). ESI(-)-MS: m/z(%) = 184 (100) $[M-H]^-$. Anal. Calcd for $C_{12}H_{11}NO$: C, 77.81; H, 5.99; N, 7.56. Found: C, 77.96; H, 6.00; N, 7.57.

*Ethyl 2,7-dimethyl-4H-furo[3,2-b]indole-4-carboxylate (**1c**).* General procedure was followed using 2,7-dimethyl-4*H*-furo[3,2-*b*]indole (500 mg, 2.7 mmol), *n*-butyllithium (1.6 M in hexane, 1.85 mL, 2.97 mmol), ethyl chloroformate (388 µL, 4.05 mmol) in THF (28 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 98:2), yielded **1c** (431 mg, 62%) as pink solid (m.p. 93.8-94.5° C). ^1H NMR (300 MHz, $CDCl_3$): 8.14 (s, 1H), 7.37 (s, 1H), 7.06 (d, J = 8.4 Hz, 1H), 6.43 (s, 1H), 4.49 (q, J = 7.1 Hz, 2H), 2.48 (s, 3H), 2.45 (s, 3H), 1.49 (t, J = 7.1 Hz, 3H). $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$): 156.0 (C), 151.1 (C), 141.6 (C), 136.1 (C), 132.8 (2xC), 124.2 (CH), 118.4 (C), 115.84 (CH), 115.78 (CH), 99.4 (CH), 62.7 (CH_2), 21.4 (CH_3), 14.7 (CH_3), 14.4 (CH_3). ESI(+)-MS: m/z(%) = 258 (100) $[M+H]^+$. Anal. Calcd for $C_{15}H_{15}NO_3$: C, 70.02; H, 5.88; N, 5.44. Found: C, 69.93; H, 5.87; N, 5.45.

4-fluoro-2-(5-methylfuran-2-yl)aniline. General procedure was followed using (5-methylfuran-2-yl)boronic acid (1.49 g, 11.8 mmol), potassium carbonate (4.40 g, 31.6 mmol), $PdCl_2(PPh_3)_2$ (273 mg, 0.39 mmol), 2-bromo-4-fluoroaniline (900 µL, 7.9 mmol) in DMF (35 mL) and water (8 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 95:5), yielded (1.31 g, 87%) as orange oil. ^1H NMR (300 MHz, $CDCl_3$): 7.19 (dd, J = 9.9, 2.9 Hz, 1H), 6.79 (td, J = 8.4, 2.9 Hz, 1H), 6.66 (dd, J = 8.8, 4.9 Hz, 1H), 6.50 (d, J = 3.2 Hz, 1H), 6.10 (m, 1H), 4.14 (s, 2H), 2.38 (s, 3H). $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$): 156.2 (d, J = 235 Hz, C), 151.6 (C), 150.3 (d, J = 2.8 Hz, C), 138.8 (d, J = 2.0 Hz, C), 117.6 (d, J = 8.0 Hz, CH), 117.5 (C), 114.7 (d, J = 22.7 Hz, CH), 112.9 (d, J = 24.0 Hz, CH), 108.3 (CH), 107.5 (CH), 13.6 (CH_3). ESI(+)-MS: m/z (%) = 192 (100) $[M+H]^+$. Anal. Calcd for $C_{12}H_{10}FNO$: C, 69.10; H, 5.27; N, 7.33. Found: C, 68.91; H, 5.25; N, 7.54.

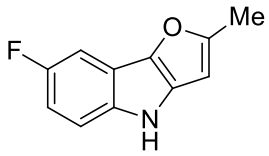


2-(2-azido-5-fluorophenyl)-5-methylfuran. General procedure (method A) was followed using 4-fluoro-2-(5-methylfuran-2-yl)aniline (1.30 g, 6.7 mmol), HCl (15%, 6.7 mL), a solution of sodium nitrite (554 mg, 8.04 mmol) in water (18 mL), a solution of sodium azide (709 mg, 10.9 mmol) in water (2.5 mL). Purification by flash column chromatography (SiO_2, hexane 100%), yielded 2-(2-azido-5-fluorophenyl)-5-methylfuran



(881 mg, 61%) as yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.52 (dd, *J* = 10, 2.9 Hz, 1H), 7.13 (dd, *J* = 8.8, 4.7 Hz, 1H), 7.02 (d, *J* = 3.3 Hz, 1H), 6.94 (ddd, *J* = 8.8, 7.5, 3.0 Hz, 1H), 6.11 (m, 1H), 2.41 - 2.33 (m, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 160.0 (d, *J* = 243 Hz, C), 152.3 (C), 146.9 (C), 130.2 (C), 124.3 (C), 120.1 (d, *J* = 8.8 Hz, CH), 114.0 (d, *J* = 23.9 Hz, CH), 112.7 (d, *J* = 26.4 Hz, CH), 112.4 (CH), 108.2 (CH), 13.6 (CH_3). Anal. Calcd for $C_{11}H_8FN_3O$: C, 60.83; H, 3.71; N, 19.35. Found: C, 60.96; H, 3.72; N, 19.31.

7-fluoro-2-methyl-4H-furo[3,2-b]indole. General procedure was followed using 1,2-dichlorobenzene

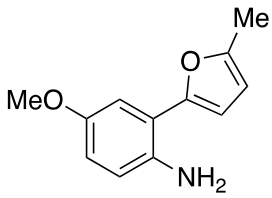


(5.5 mL), 2-(2-azido-5-fluorophenyl)-5-methylfuran (668 mg, 3.08 mmol). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 9:1), yielded 7-fluoro-2-methyl-4*H*-furo[3,2-*b*]indole (548 mg, 94%) as reddish oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.53 (s, 1H), 7.34 - 7.22 (m, 2H), 6.86 (td, *J* = 9.1, 2.5 Hz, 1H), 6.20 (d, *J* = 0.9 Hz, 1H), 2.49 (s, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 157.8 (d, *J* = 234 Hz, C), 156.9 (C), 140.6 (C), 135.5 (C), 133.0 (C), 114.6 (d, *J* = 10.8 Hz, C), 112.4 (d, *J* = 9.8 Hz, CH), 108.5 (d, *J* = 26.1 Hz, CH), 101.1 (d, *J* = 25.6 Hz, CH), 95.8 (CH), 14.9 (CH_3). ESI(+)-MS: m/z(%) = 190 (100) $[M+H]^+$. Anal. Calcd for $C_{11}H_8FNO$: C, 69.83; H, 4.26; N, 7.40. Found: C, 69.73; H, 4.25; N, 7.41.

*Ethyl 7-fluoro-2-methyl-4H-furo[3,2-b]indole-4-carboxylate (**1d**)*. General procedure was followed using 7-fluoro-4*H*-furo[3,2-*b*]indole (522 mg, 2.9 mmol), *n*-butyllithium (1.6 M in hexane, 2 mL, 3.2 mmol), ethyl chloroformate (416 μL, 4.35 mmol) in THF (30 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 98:2), yielded **1d** (569 mg, 75%) as orange solid (m.p. 91-92° C). ^{1}H NMR (300 MHz, $CDCl_3$): 8.23 (s, 1H), 7.23 (dd, *J* = 8.7, 2.6 Hz, 1H), 6.96 (dt, *J* = 9.1, 4.6 Hz, 1H), 6.44 (s, 1H), 4.51 (q, *J* = 7.1 Hz, 2H), 2.50 (d, *J* = 1.0 Hz, 3H), 1.51 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 159.6 (d, *J* = 239 Hz, C), 157.0 (C), 150.9 (C), 141.0 (d, *J* = 3.4 Hz, C), 134.2 (C), 131.9 (d, *J* = 4.2 Hz, C), 118.8 (d, *J* = 10.8 Hz, C), 117.1 (d, *J* = 9.4 Hz, CH), 110.2 (d, *J* = 24.9 Hz, CH), 101.9 (d, *J* = 26.0 Hz, CH), 99.4 (CH), 63.0 (CH_2), 14.8 (CH_3), 14.4 (CH_3).

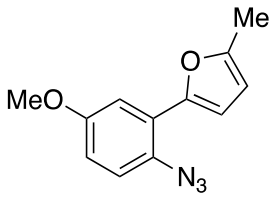
ESI(+)-MS: m/z(%) = 262 (100) $[M+H]^+$. Anal. Calcd for $C_{14}H_{12}FNO_3$: C, 64.36; H, 4.63; N, 5.36. Found: C, 64.25; H, 4.64; N, 5.35

4-methoxy-2-(5-methylfuran-2-yl)aniline. General procedure was followed using (5-methylfuran-2-



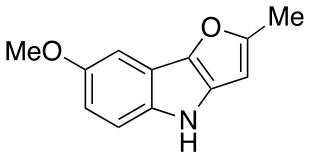
yl)boronic acid (1.39 g, 11.1 mmol), potassium carbonate (4.09 g, 29.6 mmol), PdCl2(PPh3)2 (260 mg, 0.37 mmol), 2-bromo-5-methoxyaniline (1.5 g, 7.4 mmol) in DMF (33 mL) and water (7.5 mL). Purification by flash column chromatography (SiO2, hexane/ethyl acetate 9:1), yielded 4-methoxy-2-(5-methylfuran-2-yl)aniline (1.19 g, 79%) as a red oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.05 (t, *J* = 1.7 Hz, 1H), 6.71 (d, *J* = 1.6 Hz, 2H), 6.50 (m, 1H), 6.09 (dt, *J* = 3.2, 1.0 Hz, 1H), 3.99 (bs, 2H), 3.79 (s, 3H), 2.38 (m, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 152.7 (C), 151.3 (C), 151.1 (C), 136.4 (C), 118.2 (CH), 117.7 (C), 114.9 (CH), 111.7 (CH), 107.9 (CH), 107.4 (CH), 55.8 (CH_3), 13.7 (CH_3). ESI(+)-MS: m/z(%) = 204 (100) $[M+H]^+$. Anal. Calcd for $C_{12}H_{13}NO_2$: C, 70.92; H, 6.45; N, 6.89. Found: C, 71.08; H, 6.47; N, 6.87.

2-(2-azido-5-methoxyphenyl)-5-methylfuran. General procedure (method A) was followed using 4-



methoxy-2- (5-methylfuran-2-yl)aniline (850 mg, 4.2 mmol), HCl (15%, 4.2 ml), a solution of sodium nitrite (346 mg, 5.04 mmol) in water (10.5 mL), a solution of sodium azide (444 mg, 6.8 mmol) in water (1.7 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 99:1), yielded 2-(2-azido-5-methoxyphenyl)-5-methylfuran (242 mg, 25%) as brownish oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.35 (d, *J* = 2.9 Hz, 1H), 7.11 (d, *J* = 8.8 Hz, 1H), 6.98 (d, *J* = 3.2 Hz, 1H), 6.81 (dd, *J* = 8.8, 2.9 Hz, 1H), 6.09 (dd, *J* = 3.3, 1.0 Hz, 1H), 3.85 (s, 3H), 2.37 (s, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 156.9 (C), 151.8 (C), 147.8 (C), 127.2 (C), 123.6 (C), 120.0 (CH), 113.7 (CH), 111.8 (CH), 110.9 (CH), 108.0 (CH), 55.6 (CH_3), 13.6 (CH_3). Anal. Calcd for $C_{12}H_{11}N_3O_2$: C, 62.87; H, 4.84; N, 18.33. Found: C, 62.79; H, 4.82; N, 18.38.

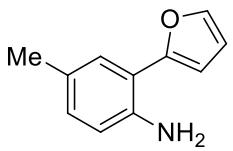
7-methoxy-2-methyl-4H-furo[3,2-b]indole. General procedure was followed using 1,2-



dichlorobenzene (3 mL), 2-(2-azido-5-methoxyphenyl)-5-methylfuran (220 mg, 0.96 mmol). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 95:5), yielded 7-methoxy-2-methyl-4*H*-furo[3,2-*b*]indole (76 mg, 39%) as brownish oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.45 (bs, 1H), 7.24 (d, J = 8.9 Hz, 1H), 7.14 (d, J = 2.5 Hz, 1H), 6.78 (dd, J = 8.9, 2.5 Hz, 1H), 6.18 (d, J = 1.0 Hz, 1H), 3.87 (s, 3H), 2.49 (d, J = 1.0 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 156.2 (C), 154.1 (C), 140.8 (C), 134.2 (C), 132.1 (C), 114.8 (C), 112.7 (CH), 110.2 (CH), 98.3 (CH), 95.9 (CH), 55.9 (CH_3), 14.9 (CH_3). ESI(+)-MS: m/z(%) = 202 (100) $[M+H]^+$. Anal. Calcd for $C_{12}H_{11}NO_2$: C, 71.63; H, 5.51; N, 6.96. Found: C, 71.88; H, 5.49; N, 6.98.

*Ethyl 7-methoxy-2-methyl-4H-furo[3,2-b]indole-4-carboxylate (**1e**).* General procedure was followed using 7-methoxy-2-methyl-4H-furo[3,2-b]indole (76 mg, 0.38 mmol), *n*-butyllithium (1.6 M in hexane, 260 µL, 0.42 mmol), ethyl chloroformate (56 µL, 0.58 mmol) in THF (11 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 99:1), yielded **1e** (80 mg, 77%) as white solid (m.p. 86.1-88.0° C). ^{1}H NMR (300 MHz, $CDCl_3$): 8.19 (bs, 1H), 7.09 (d, J = 2.5 Hz, 1H), 6.86 (dd, J = 9.1, 2.6 Hz, 1H), 6.44 (bs, 1H), 4.50 (q, J = 7.1 Hz, 2H), 3.89 (s, 3H), 2.50 (d, J = 1.0 Hz, 3H), 1.50 (t, J = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 156.3 (C), 151.1 (C), 141.6 (C), 132.5 (C), 130.9 (C), 118.9 (C), 117.0 (CH), 110.8 (CH), 99.5 (CH), 99.4 (CH), 62.8 (CH_2), 55.7 (CH_3), 14.8 (CH_3), 14.5 (CH_3). One quaternary carbon is missing, probably overlapped. ESI(+)-MS: m/z(%) = 274 (100) $[M+H]^+$. Anal. Calcd for $C_{15}H_{15}NO_4$: C, 65.92; H, 5.53; N, 5.13. Found: C, 66.17; H, 5.54; N, 5.11.

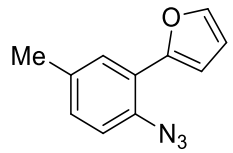
2-(furan-2-yl)-4-methylaniline. General procedure was followed using furan-2-ylboronic acid (1.95



g, 17.4 mmol), potassium carbonate (6.41 g, 46.4 mmol), $PdCl_2(PPh_3)_2$ (407 mg, 0.58 mmol), 2-bromo-4-methylaniline (2.16 g, 11.6 mmol) in DMF (52 mL) and water (12 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 97:3),

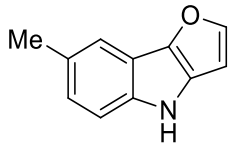
yielded 2-(furan-2-yl)-4-methylaniline (1.87 g, 93%) as brownish oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.52 (m, 1H), 7.32 (d, *J* = 1.4 Hz, 1H), 6.96 (m, 1H), 6.70 (d, *J* = 8.1 Hz, 1H), 6.60 (d, *J* = 3.4 Hz, 1H), 6.53 (dd, *J* = 3.4, 1.8 Hz, 1H), 4.13 (bs, 2H), 2.30 (s, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 153.6 (C), 141.2 (CH), 140.7 (C), 129.6 (CH), 127.9 (CH), 127.7 (C), 117.0 (CH), 116.3 (C), 111.3 (CH), 106.4 (CH), 20.4 (CH_3). ESI(+)-MS: m/z(%) = 174 (100) $[M+H]^+$. Anal. Calcd for $C_{11}H_{11}NO$: C, 76.28; H, 6.40; N, 8.09. Found: C, 76.43; H, 6.39; N, 8.10.

2-(2-azido-5-methylphenyl)furan. General procedure (method A) was followed using 2-(furan-2-yl)-



4-methylaniline (1.84 g, 10.62 mmol), a solution of HCl (2.13 mL, 70.09 mmol) in water (9.7 mL), a solution of sodium nitrite (1.76 g, 25.49 mmol) in water (9.9 mL), a solution of sodium azide (1.66 g, 25.49 mmol) in water (13.5 mL). Purification by flash column chromatography (SiO_2, hexane 100%), yielded 2-(2-azido-5-methylphenyl)furan (1.71 g, 80%) as brownish oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.66 (s, 1H), 7.47 (d, *J* = 1.0 Hz, 1H), 7.11 (s, 2H), 7.05 (d, *J* = 3.3 Hz, 1H), 6.50 (dd, *J* = 3.3, 1.8 Hz, 1H). 2.37 (s, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 149.8 (C), 141.6 (CH), 134.6 (C), 132.4 (C), 128.8 (CH), 127.3 (CH), 122.2 (C), 118.8 (CH), 111.7 (CH), 110.2 (CH), 20.9 (CH_3). Anal. Calcd for $C_{11}H_9N_3O$: C, 66.32; H, 4.55; N, 21.09. Found: C, 66.47; H, 4.55; N, 21.08.

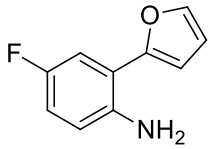
7-methyl-4H-furo[3,2-b]indole. General procedure was followed using 1,2-dichlorobenzene (8 mL),



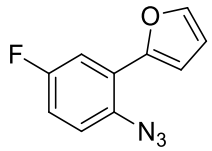
2-(2-azido-5-methylphenyl)furan (1.02 g, 5.09 mmol). Purification by flash column chromatography (SiO_2, hexane 100% to hexane/ethyl acetate 95:5), yielded 7-methyl-4*H*-furo[3,2-*b*]indole (834 mg, 95%) as reddish oil in a mixture with unidentified inseparable impurity. ^{1}H NMR (300 MHz, $CDCl_3$) for 7-methyl-4*H*-furo[3,2-*b*]indole: 7.53 (m, 3H), 7.27 (m, 1H), 7.03 (m, 1H), 6.55 (d, *J* = 2.1 Hz, 1H), 2.48 (s, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 145.6 (CH), 138.4 (C), 130.3 (C), 129.2 (C), 126.7 (C), 123.1 (CH), 116.1 (CH), 114.8 (C), 111.8 (CH), 99.4 (CH), 21.4 (CH_3). ESI(+)-MS: m/z(%) = 172 (100) $[M+H]^+$. Anal. Calcd for $C_{11}H_9NO$: C, 77.17; H, 5.30; N, 8.18. Found: C, 77.38; H, 5.31; N, 4.17.

*Ethyl 7-methyl-4H-furo[3,2-b]indole-4-carboxylate (**1f**).* General procedure was followed using 7-methyl-4*H*-furo[3,2-*b*]indole (800 mg, 4.67 mmol), *n*-butyllithium (1.6 M in hexane, 3.2 mL, 5.14 mmol), ethyl chloroformate (668 µL, 7 mmol) in THF (46 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 95:5), yielded **1f** (829 mg, 73%) as orange solid (m.p. 95-95.7° C). ^{1}H NMR (300 MHz, $CDCl_3$): 8.17 (bs, 1H), 7.51 (d, *J* = 1.9 Hz, 1H), 7.45 (dd, *J* = 1.6, 0.8 Hz, 1H), 7.12 (dd, *J* = 8.5, 1.2 Hz, 1H). 6.79 (s, 1H), 4.51 (q, *J* = 7.1 Hz, 2H), 2.47 (s, 3H), 1.50 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 151.0 (C), 145.6 (CH), 143.4 (C), 137.0 (C), 133.0 (C), 129.6 (C), 125.1 (CH), 118.2 (C), 116.4 (CH), 116.0 (CH), 103.0 (CH), 62.9 (CH_2), 21.3 (CH_3), 14.4 (CH_3). ESI(+)-MS: m/z(%) = 266 (100) $[M+Na]^+$. Anal. Calcd for $C_{14}H_{13}NO_3$: C, 69.12; H, 5.39; N, 5.76. Found: C, 69.26; H, 5.40; N, 5.77.

4-fluoro-2-(furan-2-yl)aniline. General procedure was followed using furan-2-ylboronic acid (2.65 g, 23.68 mmol), potassium carbonate (8.73 g, 63.16 mmol), $PdCl_2(PPh_3)_2$ (8.73 g, 63.16 mmol), 2-bromo-4-fluoroaniline (3.00 g, 15.79 mmol) in DMF (71 mL) and water (16 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 9:1), yielded 4-fluoro-2-(furan-2-yl)aniline (3.08 g, 100%) as brownish oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.50 (dd, *J* = 1.8, 0.7 Hz, 1H), 7.20 (dd, *J* = 9.8, 2.9 Hz, 1H), 6.83 (ddd, *J* = 8.8, 7.9, 2.9 Hz, 1H), 6.68 (dd, *J* = 8.8, 4.8 Hz, 1H), 6.61 (dd, *J* = 3.4, 0.7 Hz, 1H), 6.52 (dd, *J* = 3.4, 1.9 Hz, 1H), 4.18 (bs, 2H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 156.1 (d, *J* = 235 Hz, C), 152.2 (d, *J* = 2.6 Hz, C), 141.6 (CH), 139.2 (d, *J* = 1.7 Hz, C), 117.7 (d, *J* = 7.8 Hz, CH), 117.0 (d, *J* = 7.8 Hz, C), 115.4 (d, *J* = 22.8 Hz, CH), 113.3 (d, *J* = 23.9 Hz, CH), 111.4 (CH), 107.2 (CH). ESI(+)-MS: m/z(%) = 178 (100) $[M+H]^+$. Anal. Calcd for $C_{10}H_8FNO$: C, 67.79; H, 4.55; N, 7.91. Found: C, 67.66; H, 4.56; N, 7.92.

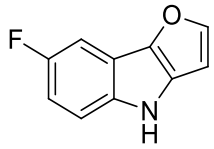


2-(2-azido-5-fluorophenyl)furan. General procedure (method A) was followed using 4-fluoro-2-(furan-2-yl)aniline (3.02 g, 17.07 mmol), a solution of HCl (3.42 mL, 112.66 mmol) in water (15 mL), a solution of sodium nitrite (2.83 g, 40.97 mmol) in water (15 mL), a solution of sodium azide (2.66 g, 40.97 mmol) in water (22 mL). Purification by flash column chromatography (SiO_2, hexane 100%), yielded 2-(2-azido-5-fluorophenyl)furan (1.42 g,



41%) as brownish oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.58 (dd, *J* = 9.8, 2.9 Hz, 1H), 7.50 (d, *J* = 1.1 Hz, 1H), 7.19 - 7.12 (m, 2H), 7.01(ddd, *J* = 8.8, 7.5, 2.9 Hz, 1H), 6.54 (ddd, *J* = 3.5, 1.8, 0.7 Hz, 1H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 160.3 (d, *J* = 243 Hz, C), 149.2 (C), 142.8 (CH), 131.3 (d, *J* = 2.6 Hz, C), 124.4 (d, *J* = 8.7 Hz, C), 120.8 (d, *J* = 8.7 Hz, CH), 115.3 (d, *J* = 23.7 Hz, CH), 113.8 (d, *J* = 25.3 Hz, CH), 112.5 (CH), 111.9 (CH). Anal. Calcd for $C_{10}H_6FN_3O$: C, 59.12; H, 2.98; N, 20.68. Found: C, 59.23; H, 2.97; N, 20.60.

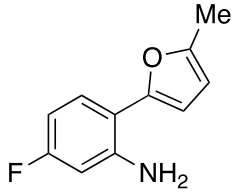
7-fluoro-4H-furo[3,2-b]indole. General procedure was followed using 1,2-dichlorobenzene (11 mL),



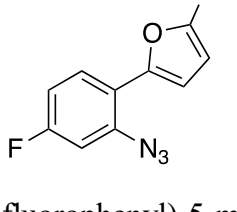
2-(2-azido-5-fluorophenyl)furan (1.37 g, 6.7 mmol). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 95:5), yielded 7-fluoro-4*H*-furo[3,2-*b*]indole (788 mg, 67%) as reddish wax. ^{1}H NMR (300 MHz, $CDCl_3$): 7.64 (bs, 1H), 7.58 (d, *J* = 2.1 Hz, 1H), 7.41 (dd, *J* = 9.3, 2.5 Hz, 1H), 7.32 (dd, *J* = 8.9, 4.3 Hz, 1H), 6.99 (td, *J* = 9.1, 2.6 Hz, 1H), 6.58 (d, *J* = 2.1 Hz, 1H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 158.2 (d, *J* = 235 Hz, C), 146.9 (CH), 142.5 (C), 136.8 (C), 132.2 (C), 114.9 (C), 113.1 (d, *J* = 9.7 Hz CH), 110.0 (d, *J* = 26.1 Hz, CH), 102.2 (d, *J* = 25.6 Hz, CH), 99.9 (CH). ESI(-)-MS: m/z(%) = 174 (100) $[M-H]^-$. Anal. Calcd for $C_{10}H_6FNO$: C, 68.57; H, 3.45; N, 8.00. Found: C, 68.54; H, 3.46; N, 7.99.

*Ethyl 7-fluoro-4H-furo[3,2-b]indole-4-carboxylate (**1g**).* General procedure was followed using 7-fluoro-4*H*-furo[3,2-*b*]indole (765 mg, 4.37 mmol), *n*-butyllithium (1.6 M in hexane, 3 mL, 4.81 mmol), ethyl chloroformate (627 µL, 6.55 mmol) in THF (43 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 99:1), yielded **1g** (855 mg, 79%) as orange solid (m.p. 60-61° C). ^{1}H NMR (300 MHz, $CDCl_3$): 8.27 (bs, 1H), 7.56 (d, *J* = 2.0 Hz, 1H), 7.33 (dd, *J* = 8.6, 2.6 Hz, 1H), 7.03 (td, *J* = 9.1, 2.6 Hz, 1H), 6.82 (s, 1H), 4.53 (q, *J* = 7.1 Hz, 2H), 1.52 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 159.5 (d, *J* = 240 Hz, C), 150.9 (C), 146.4 (CH), 142.8 (C), 135.0 (C), 131.0 (C), 118.6 (d, *J* = 10.9 Hz, C), 117.3 (d, *J* = 9.2 Hz, CH), 111.2 (d, *J* =25.3 Hz, CH), 103.1 (CH), 102.6 (d, *J* = 25.9 Hz, CH), 63.2 (CH_2), 14.4 (CH_3). ESI(+)-MS: m/z(%) = 248 (100) $[M+H]^+$. Anal. Calcd for $C_{13}H_{10}FNO_3$: C, 63.16; H, 4.08; N, 5.67. Found: C, 63.24; H, 4.07; N, 5.68.

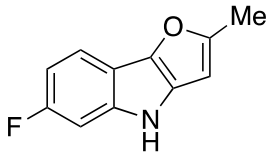
5-fluoro-2-(5-methylfuran-2-yl)aniline. General procedure was followed using (5-methylfuran-2-yl)boronic acid (1.13 g, 9 mmol), potassium carbonate (3.30 g, 24 mmol), $PdCl_2(PPh_3)_2$ (211 mg, 0.3 mmol), 2-bromo-5-fluoroaniline (1.14 g, 6 mmol) in DMF (27 mL) and water (6 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 9:1), yielded 5-fluoro-2-(5-methylfuran-2-yl)aniline (907 mg, 79%) as a yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.39 (dd, *J* = 8.6, 6.4 Hz, 1H), 6.51 (dd, *J* = 8.4, 2.5 Hz, 1H), 6.47 (m, 1H), 6.42 (dd, *J* = 8.4, 2.8 Hz, 1H), 6.10 (m, 1H), 4.39 (bs, 2H), 2.39 (s, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 163.0 (d, *J* = 243 Hz, C), 151.1 (C), 150.8 (C), 144.8 (C), 144.7 (d, *J* = 10.9 Hz, C), 129.0 (d, *J* = 10 Hz, CH), 112.9 (d, *J* = 2.6 Hz, C), 107.2 (d, *J* = 17.7 Hz, CH), 105.4 (d, *J* = 23 Hz, CH), 103.0 (CH), 102.6 (CH), 13.7 (CH_3). ESI(+)-MS: m/z(%) = 192 (100) $[M+H]^+$. Anal. Calcd for $C_{11}H_{10}FNO$: C, 69.10; H, 5.27; N, 7.33. Found: C, 68.84; H, 5.25; N, 7.35.



2-(2-azido-4-fluorophenyl)-5-methylfuran. General procedure (method B) was followed using 5-fluoro-2-(5- methylfuran-2-yl)aniline (570 mg, 2.98 mmol), *t*-BuONO (0.53 ml, 4.47 mmol) and $TMSN_3$ (0.59 ml, 4.47 mmol) in CH_3CN (6 ml). Purification by flash column chromatography (SiO_2, hexane 100%), yielded 2-(2-azido-4-fluorophenyl)-5-methylfuran (390 mg, 60%) as a yellow wax. ^{1}H NMR (300 MHz, $CDCl_3$): 7.79 (dd, *J* = 8.6, 6.2 Hz, 1H), 6.96-6.87 (m, 3H), 6.10 (m, 1H), 2.38 (s, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 161.7 (d, *J* = 249 Hz, C), 151.7 (C), 147.2 (C), 136.1 (d, *J* = 8 Hz, C), 127.9 (d, *J* = 11 Hz, CH), 119.2 (C), 112.2 (d, *J* = 22 Hz, CH), 110.9 (CH), 107.9 (CH), 106.1 (d, *J* = 24 Hz, CH), 13.6 (CH_3). Anal. Calcd for $C_{11}H_8FN_3O$: C, 60.83; H, 3.71; N, 19.35. Found: C, 61.04; H, 3.72; N, 19.29.



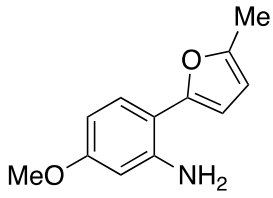
6-fluoro-2-methyl-4H-furo[3,2-b]indole. General procedure was followed using 1,2-dichlorobenzene (4 mL), 2-(2-azido-4-fluorophenyl)-5-methylfuran (370 mg, 1.71 mmol). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 9:1), yielded 6-fluoro-2-methyl-4*H*-furo[3,2-*b*]indole (221 mg, 68%) as brownish oil. ^{1}H NMR (300 MHz, $CDCl_3$): 7.67-7.48 (m, 2H), 7.08 (dd, *J* = 9.9, 2.1 Hz, 1H), 6.93 (m, 1H),



6.22 (d, J = 1.0 Hz, 1H), 2.50 (d, J = 0.8 Hz, 3H). $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$): 159.3 (d, J = 237 Hz, C), 156.2 (C), 140.7 (C), 139.3 (d, J = 11.8 Hz, C), 131.5 (C), 116.3 (d, J = 10 Hz, CH), 112.1 (C), 108.4 (d, J = 24.4 Hz, CH), 99.2 (d, J = 26.6 Hz, CH), 96.4 (CH), 15.3 (CH_3). ESI(+)-MS: m/z(%) = 190 (100) $[M+H]^+$. Anal. Calcd for $C_{11}H_8FNO$: C, 69.84; H, 4.26; N, 7.40. Found: C, 7.02; H, 4.28; N, 7.37.

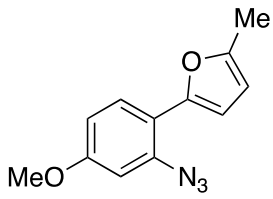
Ethyl 6-fluoro-2-methyl-4H-furo[3,2-b]indole-4-carboxylate (***1h***). General procedure was followed using 6-fluoro-2-methyl-4*H*-furo[3,2-*b*]indole (208 mg, 1.1 mmol), *n*-butyllithium (1.6 M in hexane, 760 µL, 1.21 mmol), ethyl chloroformate (158 µL, 1.65 mmol) in THF (11 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 99:1 to 98:2), yielded **1h** (266 mg, 93%) as white solid (m.p. 100.9-102.8° C). ^1H NMR (300 MHz, $CDCl_3$): 8.04 (bs, 1H), 7.47 (dd, J = 8.6, 5.4 Hz, 1H), 7.01 (m, 1H), 6.41 (bs, 1H), 4.49 (q, J = 7.1 Hz, 2H), 2.47 (d, J = 0.9 Hz, 3H), 1.49 (t, J = 7.1 Hz, 3H). $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$): 159.8 (d, J = 240 Hz, C), 156.0 (C), 150.9 (C), 141.1 (C), 130.4 (C), 115.9 (d, J = 9.6 Hz, CH), 114.9 (C), 111.0 (d, J = 24.2 Hz, CH), 104.1 (d, J = 29.2 Hz, CH), 99.4 (CH), 63.1 (CH_2), 14.7 (CH_3), 14.4 (CH_3). One quaternary carbon is missing, probably overlapped. ESI(+)-MS: m/z(%) = 262 (100) $[M+H]^+$. Anal. Calcd for $C_{14}H_{12}FNO_3$: C, 64.36; H, 4.63; N, 5.36. Found: C, 64.44; H, 4.61; N, 5.35.

5-methoxy-2-(5-methylfuran-2-yl)aniline. General procedure was followed using (5-methylfuran-2-yl)boronic acid (1.13 g, 9 mmol), potassium carbonate (3.30 g, 24 mmol), $PdCl_2(PPh_3)_2$ (211 mg, 0.3 mmol), 2-bromo-5-methoxyaniline (1.21 g, 6 mmol) in DMF (27 mL) and water (6 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 9:1), yielded 5-methoxy-2-(5-methylfuran-2-yl)aniline (903 mg, 74%) as a brownish oil. ^1H NMR (300 MHz, $CDCl_3$): 7.35 (d, J = 8.6 Hz, 1H), 6.38 (dd, J = 8.6, 2.5 Hz, 1H), 6.33 (d, J = 3.1 Hz, 1H), 6.30 (d, J = 2.4 Hz, 1H), 6.05 (m, 1H), 4.31 (bs, 2H), 3.78 (s, 3H), 2.36 (s, 3H). $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$): 160.0 (C), 151.55 (C), 150.51 (C), 144.2 (C), 128.7 (CH), 110.4 (C), 107.1 (CH), 106.1 (CH), 104.8 (CH), 101.6 (CH), 55.2 (CH_3), 13.8 (CH_3).



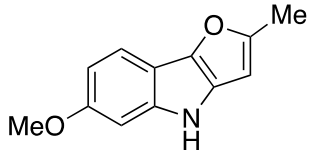
ESI(+)-MS: m/z(%) = 204 (100) $[M+H]^+$. Anal. Calcd for $C_{12}H_{13}NO_2$: C, 70.92; H, 6.45; N, 6.89. Found: C, 71.08; H, 6.47; N, 6.91.

2-(2-azido-4-methoxyphenyl)-5-methylfuran. General procedure (method B) was followed using 5-



methoxy-2-(5-methylfuran-2-yl)aniline (900 mg, 4.43 mmol), *t*-BuONO (0.79 ml, 6.65 mmol) and $TMSN_3$ (0.87 ml, 6.65 mmol) in CH_3CN (9 ml). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 98:2), yielded 2-(2-azido-4-methoxyphenyl)-5-methylfuran (810 mg, 80%) as a yellow wax. ^1H NMR (300 MHz, $CDCl_3$): 7.73 (dd, J = 7.6, 1.6 Hz, 1H), 6.81 (d, J = 3.2 Hz, 1H), 6.78 – 6.73 (m, 2H), 6.08 (m, 1H), 3.87 (s, 3H), 2.38 (d, J = 0.4 Hz, 3H). ^{13}C {^1H} NMR (75 MHz, $CDCl_3$): 159.1 (C), 151.0 (C), 148.1 (C), 135.8 (C), 127.6 (CH), 116.3 (C), 110.7 (CH), 109.6 (CH), 107.7 (CH), 104.6 (CH), 55.5 (CH_3), 13.6 (CH_3). Anal. Calcd for $C_{12}H_{11}N_3O_2$: C, 62.87; H, 4.84; N, 18.33. Found: C, 62.79; H, 4.86; N, 18.37.

6-methoxy-2-methyl-4H-furo[3,2-b]indole.

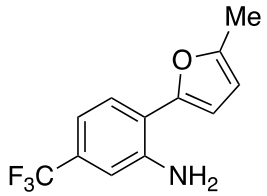


General procedure was followed using 1,2-dichlorobenzene (8 mL), 2-(2-azido-4-methoxyphenyl)-5-methylfuran (808 mg, 3.5 mmol). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 9:1), yielded 6-methoxy-2-methyl-4*H*-furo[3,2-*b*]indole (430 mg, 61%) as brownish oil. ^1H NMR (300 MHz, $CDCl_3$): 7.55 (m, 2H), 6.89 (d, J = 2.2 Hz, 1H), 6.83 (dd, J = 8.6, 2.2 Hz, 1H), 6.19 (s, 1H), 3.86 (s, 3H), 2.50 (s, 3H). ^{13}C {^1H} NMR (75 MHz, $CDCl_3$): 155.4 (C), 154.7 (C), 140.6 (C), 140.0 (C), 129.9 (C), 116.0 (CH), 109.8 (C), 108.6 (CH), 96.7 (CH), 96.0 (CH), 55.8 (CH_3), 14.9 (CH_3). ESI(+)-MS: m/z(%) = 202 (100) $[M+H]^+$. Anal. Calcd for $C_{12}H_{11}NO_2$: C, 71.63; H, 5.51; N, 6.96. Found: C, 71.88; H, 5.50; N, 6.94.

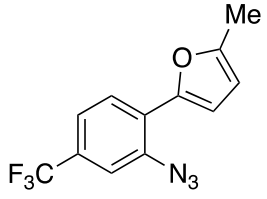
*Ethyl 6-methoxy-2-methyl-4H-furo[3,2-b]indole-4-carboxylate (**1i**).* General procedure was followed using 6-methoxy-2-methyl-4*H*-furo[3,2-*b*]indole (395 mg, 1.91 mmol), *n*-butyllithium (1.6 M in hexane, 1.3 mL, 2.10 mmol), ethyl chloroformate (274 μL, 2.86 mmol) in THF (11 mL). Purification

by flash column chromatography (SiO_2, hexane/ethyl acetate 95:5), yielded **1i** (447 mg, 86%) as white solid (m.p. 95.6-97.7 ° C). ^{1}H NMR (300 MHz, $CDCl_3$): 7.93 (bs, 1H), 7.45 (d, *J* = 8.6 Hz, 1H), 6.89 (dd, *J* = 8.6, 2.4 Hz, 1H), 6.40 (bs, 1H), 4.48 (q, *J* = 7.1 Hz, 2H), 3.88 (s, 3H), 2.46 (d, *J* = 1.0 Hz, 3H), 1.49 (t, *J* = 7.1 Hz, 3H). ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$): 156.8 (C), 154.9 (C), 151.2 (C), 141.7 (C), 139.1 (C), 129.0 (C), 116.0 (CH), 112.7 (C), 111.5 (CH), 101.5 (CH), 99.5 (CH), 62.8 (CH_2), 55.7 (CH_3), 14.6 (CH_3), 14.4 (CH_3). ESI(+)-MS: m/z(%) = 274 (100) $[M+H]^+$. Anal. Calcd for $C_{15}H_{15}NO_4$: C, 65.92; H, 5.53; N, 5.13. Found: C, 65.84; H, 5.51; N, 5.14.

2-(5-methylfuran-2-yl)-5-(trifluoromethyl)aniline. General procedure was followed using (5-methylfuran-2-yl)boronic acid (1.13 g, 9 mmol), potassium carbonate (3.30 g, 24 mmol), $PdCl_2(PPh_3)_2$ (211 mg, 0.3 mmol), 2-bromo-5-(trifluoromethyl)aniline (1.44 g, 6 mmol) in DMF (27 mL) and water (6 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 95:5), yielded 2-(5-methylfuran-2-yl)-5-(trifluoromethyl)aniline (1.37 mg, 95%) as a white wax. ^{1}H NMR (500 MHz, $CDCl_3$): 7.56 (d, *J* = 8.1 Hz, 1H), 7.02 (d, *J* = 8.2 Hz, 1H), 6.98 (s, 1H), 6.58 (d, *J* = 3.3 Hz, 1H), 6.15 (m, 1H), 4.54 (bs, 2H), 2.42 (s, 3H). ^{13}C {^{1}H} NMR (125 MHz, $CDCl_3$): 152.0 (C), 150.4 (C), 142.8 (C), 129.9 (q, *J* = 33.8 Hz, C), 127.3 (CH), 122.2 (q, *J* = 272 Hz, C), 119.2 (C), 114.8 (q, *J* = 3.4 Hz, CH), 113.2 2 (q, *J* = 3.9 Hz, CH), 108.9 (CH), 107.7 (CH), 13.7 (CH_3). ESI(+)-MS: m/z(%) = 242 (100) $[M+H]^+$. Anal. Calcd for $C_{12}H_{10}F_3NO$: C, 59.75; H, 4.18; N, 5.81. Found: C, 59.91; H, 4.17; N, 5.83.

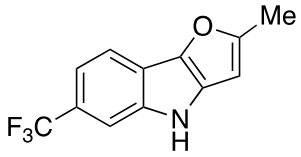


2-(2-azido-4-(trifluoromethyl)phenyl)-5-methylfuran. General procedure (method B) was followed using 2-(5-methylfuran-2-yl)-5-(trifluoromethyl)aniline (1.35 mg, 5.6 mmol), *t*-BuONO (1.0 ml, 8.4 mmol) and $TMSN_3$ (1.1 ml, 8.4 mmol) in CH_3CN (11 ml). Purification by flash column chromatography (SiO_2, hexane), yielded 2-(2-azido-4-(trifluoromethyl)phenyl)-5-methylfuran (1.33 g, 99%) as a yellow wax. ^{1}H NMR (300 MHz, $CDCl_3$): 7.92 (d, *J* = 8.6 Hz, 1H), 7.42-7.37 (m, 2H), 7.10 (d, *J* = 3.3 Hz, 1H), 6.14 (m, 1H),



2.39 (s, 3H).^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$): 152.9 (C), 146.7 (C), 134.9 (C), 129.0 (q, *J* = 32.8 Hz, C), 126.4 (CH), 125.5 (C), 121.9 (q, *J* = 271 Hz, C), 121.6 (q, *J* = 3.9 Hz, CH), 115.7 (q, *J* = 3.8 Hz, CH), 113.7 (CH), 108.4 (CH), 13.6 (CH_3). Anal. Calcd for $C_{12}H_8F_3N_3O$: C, 53.94; H, 3.02; N, 15.73. Found: C, 54.11; H, 3.01; N, 15.69.

2-methyl-6-(trifluoromethyl)-4H-furo[3,2-b]indole. General procedure was followed using 1,2-



dichlorobenzene (10.5 mL), 2-(2-azido-4-(trifluoromethyl)phenyl)-5-methylfuran (1.3 g, 4.9 mmol). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 90:10), yielded 2-methyl-6-(trifluoromethyl)-4*H*-furo[3,2-*b*]indole (873 mg, 74%) as reddish solid (m.p. 149.3-151.9 °C). ^{1}H-NMR (500 MHz, $CDCl_3$): 7.81 (s, 1H), 7.74 (d, *J* = 8.3 Hz, 1H), 7.65 (m, 1H), 7.42 (dd, *J* = 8.4, 1.0 Hz, 1H), 6.27 (d, *J* = 0.9 Hz, 1H), 2.54 (d, *J* = 0.8 Hz, 3H). ^{13}C {^{1}H} NMR (125 MHz, $CDCl_3$): 158.0 (C), 140.0 (C), 137.6 (C), 133.6 (C), 125.2 (q, *J* = 271 Hz, C), 122.5 (q, *J* = 32 Hz, C), 116.7 (q, *J* = 3.9 Hz, CH), 116.3 (C), 115.5 (CH), 109.4 (q, *J* = 4.2 Hz, CH), 95.9 (CH), 15.0 (CH_3). ESI(+)-MS: m/z(%) = 240 (100) $[M+H]^+$. Anal. Calcd for $C_{12}H_8F_3NO$: C, 60.26; H, 3.37; N, 5.86. Found: C, 60.17; H, 3.38; N, 5.84.

*Ethyl 2-methyl-6-(trifluoromethyl)-4H-furo[3,2-b]indole-4-carboxylate (**1j**).* General procedure was followed using 2-methyl-6-(trifluoromethyl)-4*H*-furo[3,2-*b*]indole (500 mg, 2.1 mmol), *n*-butyllithium (1.6 M in hexane, 1.4 mL, 2.3 mmol), ethyl chloroformate (301 µL, 3.2 mmol) in THF (21 mL). Purification by flash column chromatography (SiO_2, hexane/ethyl acetate 95:5), yielded **1j** (628 mg, 96%) as yellow solid (m.p. 107.5-109.6 ° C). ^{1}H-NMR (300 MHz, $CDCl_3$): 8.57 (s, 1H), 7.60 (d, *J* = 8.3 Hz, 1H), 7.50 (dd, *J* = 8.3, 1.0 Hz, 1H), 6.42 (s, 1H), 4.51 (q, *J* = 7.1 Hz, 2H), 2.49 (d, *J* = 0.7 Hz, 3H), 1.50 (t, *J* = 7.1 Hz, 3H). ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$): 158.0 (C), 150.7 (C), 140.6 (C), 136.8 (C), 132.7 (C), 124.7 (q, *J* = 271 Hz, C), 124.7 (q, *J* = 31.4 Hz, C), 120.2 (q, *J* = 4.1 Hz, CH), 120.1 (C), 115.5 (CH), 113.6 (q, *J* = 4.3 Hz, CH), 99.4 (CH), 63.4 (CH_2), 14.8 (CH_3), 14.3

(CH_3). ESI(+)-MS: m/z(%) = 312 (100) $[M+H]^+$. Anal. Calcd for $C_{15}H_{12}F_3NO_3$: C, 57.88; H, 3.89; N, 4.50. Found: C, 58.02; H, 3.88; N, 4.48.

Ethyl 2-bromo-4H-furo[3,2-b]indole-4-carboxylate. To a N_2 flushed solution of ethyl 4*H*-furo[3,2-*b*]indole-4-carboxylate (150 mg, 0.65 mmol) in 1,2-dichloroethane (6.5 mL), *N*-bromosuccinimide (116 mg, 0.65 mmol) and DMF (7 μL) were added. The reaction mixture was stirred at room temperature for 1 h. The mixture was quenched with $Na_2S_2O_3$ saturated solution and extracted with dichloromethane. The organic layer was washed with brine, dried over Na_2SO_4, filtered and the solvent concentrated under vacuum. The crude was purified by flash column chromatography (SiO_2, hexane/ethyl acetate 98:2) to yield ethyl 2-bromo-4H-furo[3,2-b]indole-4-carboxylate (159 mg, 79%) as white solid (m.p. 96-98° C). ^{1}H NMR (300 MHz, $CDCl_3$): 8.32 (bs, 1H), 7.64 (m, 1H), 7.44-7.06 (m, 2H), 6.80 (s, 1H), 4.53 (q, J = 7.1 Hz, 2H), 1.52 (t, J = 7.1 Hz, 3H). ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$): 150.8 (C), 143.4 (C), 137.6 (C), 129.6 (C), 125.0 (C), 124.3 (CH), 123.6 (CH), 117.6 (C), 116.3 (CH), 116.2 (CH), 105.1 (CH), 63.3 (CH_2), 14.5 (CH_3). Anal. Calcd for $C_{13}H_{10}BrNO_3$: C, 50.67; H, 3.27; N, 4.55. Found: C, 50.49; H, 3.28; N, 4.54.

*Ethyl 2-phenyl-4H-furo[3,2-b]indole-4-carboxylate (**1k**)*. To a N_2-flushed solution of phenylboronic acid (67 mg 0.54 mmol), potassium carbonate (249 mg, 1.8 mmol.), $PdCl_2(PPh_3)_2$ (16 mg, 0.02 mmol) in DMF (2 mL) and water (0.6 mL), ethyl 2-bromo-4H-furo[3,2-b]indole-4-carboxylate (140 mg 0.45 mmol)was added. The reaction mixture was heated at reflux for 1.5 h and then cooled at room temperature. The mixture was diluted with water and extracted with ethyl acetate. The organic layer was washed with brine, dried over Na_2SO_4, filtered and the solvent concentrated under vacuum. The crude was purified by flash column chromatography (SiO_2, hexane/ethyl acetate 98:2) to yield **1k** (105 mg, 76%) as white solid (m.p. 114-116° C). ^{1}H NMR (300 MHz, $CDCl_3$): 8.32 (bs, 1H), 7.81 (dd, J = 5.2, 3.3 Hz, 2H), 7.69 (m, 1H), 7.48-7.38 (m, 2H), 7.38-7.21 (m, 3H), 7.06 (bs, 1H), 4.55 (q, J = 7.1 Hz, 2H), 1.54 (t, J = 7.1 Hz, 3H). ^{13}C {^{1}H} NMR (75 MHz, $CDCl_3$): 157.3 (C), 151.1 (C),

142.9 (C), 138.5 (C), 131.1 (C), 128.8 (2xCH), 127.8 (CH), 123.9 (CH), 123.8 (2xCH), 123.5 (CH), 118.0 (C), 116.31 (CH), 116.29 (CH), 97.8 (CH), 63.1 (CH_2), 14.5 (CH_3). One quaternary carbon is missing, probably overlapped. ESI(+)-MS: m/z(%) = 306 (100) $[M+H]^+$. Anal. Calcd for $C_{19}H_{15}NO_3$: C, 74.74; H, 4.95; N, 4.59. Found: C, 74.86; H, 4.97; N, 4.58.

General Procedure for the Synthesis of Compounds 4a-m. To a N_2-flushed solution of ethyl 2-methyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1b-e**, **1h-k** (1 equiv.) and [IPrAu(NTf_2)] (5 mol%) in anhydrous dichloromethane, a solution of *N*-allenamide **2a-g** (1.2 equiv.) in dichloromethane was added dropwise at -20° C. The reaction mixture was stirred for the stated time at -20° C and then quenched with PPh_3 (15 mol%). The solvent was removed under vacuum and the crude residue was purified by flash column chromatography to yield the desired product **4a-m**.

*(E)-ethyl 3-methyl-3'-oxo-5-((2-oxooxazolidin-3-yl)methylene)spiro[cyclopent[2]ene-1,2'-indoline]-1'-carboxylate (**4a**)*. General procedure was followed using ethyl 2-methyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1b** (49 mg, 0.2 mmol), 3-(propa-1,2-dien-1-yl)oxazolidin-2-one **2a** (30 mg, 0.24 mmol) and [IPrAu(NTf_2)] (8.7 mg, 0.01 mmol) in anhydrous dichloromethane (3+1 mL) at -20° C for 1 h. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 1:1) yielded **4a** (50 mg, 68%) as a yellowish wax. ^{1}H NMR (300 MHz, C_6D_6): 8.46 (bs, 1H), 7.81 (d, *J* = 7.6 Hz, 1H), 7.30 (m, 1H, overlapping with the signal of C_6D_6), 6.79 (t, *J* = 7.4 Hz, 1H), 6.44 (s, 1H), 4.95 (s, 1H), 4.16 (q, *J* = 7.1 Hz, 2H), 3.35 (m, 2H), 3.18 (m, 2H), 2.85 (m, 1H), 2.73 (m, 1H), 1.78 (s, 3H), 1.05 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, C_6D_6): 198.0 (C), 155.4 (C), 153.0 (C), 151.6 (C), 145.4 (C), 137.1 (CH), 124.6 (CH), 123.4 (CH), 123.3 (CH), 122.3 (C), 118.5 (CH), 116.8 (CH), 82.8 (C) 61.6 (CH_2), 61.2 (CH_2), 43.4 (CH_2), 40.0 (CH_2), 16.5 (CH_3), 14.0 (CH_3). One quaternary carbon is missing, probably overlapping with C_6D_6. ESI(+)-MS: m/z (%) = 489 (100) $[M+Na]^+$. Anal. Calcd for $C_{20}H_{20}N_2O_5$: C, 65.21; H, 5.47; N, 7.60. Found: C, 65.29; H,.5.46: N, 7.59.

*(E)-ethyl-3-methyl-3'-oxo-5-((2-oxopyrrolidin-1-yl)methylene)spiro[cyclopent[2]ene-1,2'-indoline]-1'-carboxylate (**4b**).* General procedure was followed using ethyl 2-methyl-4*H*-furo[3,2-*b*]indole-4-

carboxylate **1b** (49 mg, 0.2 mmol), 1-(propa-1,2-dien-1-yl)pyrrolidin-2-one **2b** (37 mg, 0.3 mmol) and [IPrAu(NTf_2)] (8.7 mg, 0.01 mmol) in anhydrous dichloromethane (3+1 mL) at -20° C for 3 h. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 2:1) yielded **4b** (45 mg, 61%) as yellowish wax. ^{1}H NMR (300 MHz, C_6D_6): 8.50 (bs, 1H), 7.79 (dd, *J* = 7.6, 0.7 Hz, 1H), 7.32 (m, 1H), 6.93 - 6.67 (m, 2H), 4.99 (s, 1H), 4.12 (q, *J* = 7.1 Hz, 2H), 3.41 - 3.20 (m, 2H), 3.10 (m, 1H), 2.97 (m, 1H), 1.93 - 1.81 (m, 2H), 1.78 (s, 3H), 1.21 - 1.11 (m, 2H), 1.03 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, C_6D_6): 198.1 (C), 172.3 (C), 153.1 (C), 151.6 (C), 145.5 (C), 137.0 (CH), 124.6 (CH), 123.3 (CH), 123.3 (CH), 122.4 (C), 118.3 (CH), 116.8 (CH), 83.1 (C), 61.4 (CH_2), 46.2 (CH_2), 40.6 (CH_2), 29.6 (CH_2), 17.4 (CH_2), 16.5 (CH_3), 14.0 (CH_3). One quaternary carbon is missing, probably overlapping with C_6D_6. ESI(+)-MS: m/z (%) = 367 (100) $[M+H]^+$. Anal. Calcd for $C_{21}H_{22}N_2O_4$: C, 68.84; H, 6.05; N, 7.65. Found: C, 69.03; H, 6.04; N, 7.66.

*(E)-ethyl-5-((N,4-dimethylphenylsulfonamido)methylene)-3-methyl-3'-oxospiro[cyclopent[2]ene-1,2'-indoline]-1'-carboxylate (**4c**).* General procedure was followed using ethyl 2-methyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1b** (49 mg, 0.2 mmol), *N*,4-dimethyl-*N*-(propa-1,2-dien-1-yl)benzenesulfonamide **2c** (53 mg, 0.24 mmol) and [IPrAu(NTf_2)] (8.7 mg, 0.01 mmol) in anhydrous dichloromethane (3+1 mL) at -20° C for 3 h. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 9:1) yielded **4c** (72 mg, 77%) as yellowish wax. ^{1}H NMR (300 MHz, C_6D_6): 8.69 (bs, 1H), 7.79 (d, *J* = 7.6 Hz, 1H), 7.72 (d, *J* = 8.1 Hz, 2H), 7.29 (m, 1H, overlapping with the signal of C_6D_6), 6.91 (d, *J* = 8.1 Hz, 2H), 6.77 (t, *J* = 7.4 Hz, 1H), 5.62 (bs, 1H), 4.87 (s, 1H), 4.25 (q, *J* = 7.1 Hz, 2H), 3.54 - 3.24 (m, 2H), 2.55 (s, 3H), 1.93 (s, 3H), 1.63 (s, 3H), 1.09 (t, *J* = 7.1 Hz, 3H). ^{113}C{^{1}H} NMR (75 MHz, C_6D_6): 197.2 (C), 153.3 (C), 151.9 (C), 146.2 (C), 143.1 (C), 137.0 (CH), 134.4 (C), 129.5 (2xCH), 127.6 (2xCH), 124.4 (CH), 123.3 (CH), 122.5 (CH), 122.4 (CH), 122.4 (C), 116.7 (CH), 82.0 (C), 61.9 (CH_2), 40.5 (CH_2), 36.2 (CH_3), 20.8 (CH_3), 16.3 (CH_3), 13.8 (CH_3). One quaternary carbon is missing, probably overlapping with C_6D_6. ESI(+)-MS: m/z (%) = 489 (100) $[M+Na]^+$. Anal. Calcd for $C_{25}H_{26}N_2O_5S$: C, 64.36; H, 5.62; N, 6.00. Found: C, 64.18; H, 5.63; N, 5.99.

*(E)-ethyl 3-methyl-5-((4-methyl-N-phenylphenylsulfonamido)methylene)-3'-oxospiro[cyclopent[2]ene-1,2'-indoline]-1'-carboxylate (**4d**).* General procedure was followed using ethyl 2-methyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1b** (49 mg, 0.2 mmol), 4-methyl-*N*-phenyl-*N*-(propa-1,2-dien-1-yl)benzenesulfonamide **2d** (69 mg, 0.24 mmol) and [IPrAu(NTf_2)] (8.7 mg, 0.01 mmol) in anhydrous dichloromethane (3+1 mL) at -20° C for 18 h. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 9:1) yielded **4d** (52 mg, 49%) as yellowish oil. ^{1}H NMR (300 MHz, C_6D_6): 8.75 (bs, 1H), 7.81 (d, *J* = 7.6 Hz, 1H), 7.52 (d, *J* = 8.2 Hz, 2H), 7.39 - 7.20 (m, 3H, overlapped with the signal of C_6D_6), 7.10 - 6.91 (m, 3H), 6.79 (dd, *J* = 12.3, 4.7 Hz, 2H), 6.65 (d, *J* = 8.1 Hz, 2H), 4.83 (d, *J* = 1.4 Hz, 1H), 4.26 - 4.12 (m, 2H), 2.93 - 2-63 (m, 2H), 1.84 (s, 3H), 1.45 (s, 3H), 1.03 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, C_6D_6): 197.3 (C), 153.4 (C), 151.9 (C), 145.6 (C), 143.2 (C), 140.1 (C), 137.1 (CH), 135.8 (C), 129.4 (2xCH), 128.8 (2xCH), 128.1 (CH), 127.6 (2xCH), 127.0 (2xCH), 124.6 (CH), 123.3 (CH), 122.8 (CH), 122.2 (C), 122.0 (CH), 116.9 (CH), 82.2 (C), 61.8 (CH_2), 40.1 (CH_2), 20.8 (CH_3), 16.1 (CH_3), 13.8 (CH_3). One quaternary carbon is missing, probably overlapping with C_6D_6. ESI(+)-MS: m/z (%) = 551 (100) $[M+Na]^+$. Anal. Calcd for $C_{30}H_{28}N_2O_5S$: C, 68.16; H, 5.34; N, 5.30. Found: C, 68.07; H, 5.33; N, 5.29.

*(E)-ethyl 5-((N-benzyl-4-methylphenylsulfonamido)methylene)-3-methyl-3'-oxospiro[cyclopent[2]ene-1,2'-indoline]-1'-carboxylate (**4e**).* General procedure was followed using ethyl 2-methyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1b** (49 mg, 0.2 mmol), *N*-benzyl-4-methyl-*N*-(propa-1,2-dien-1-yl)benzenesulfonamide **2e** (72 mg, 0.24 mmol) and [IPrAu(NTf_2)] (8.7 mg, 0.01 mmol) in anhydrous dichloromethane (3+1 mL) at -20° C for 18 h. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 9:1 to 8:2) yielded **4e** (67 mg, 62%) as white thick wax. ^{1}H NMR (300 MHz, C_6D_6): 8.73 (d, *J* = 7.9 Hz, 1H), 7.81 (d, *J* = 8.3 Hz, 3H), 7.33 - 7.19 (m, 4H, overlapped with the signal of C_6D_6), 7.17 - 7.06 (m, 2H), 6.96 (d, *J* = 8.2 Hz, 2H), 6.76 (t, *J* = 7.4 Hz, 1H), 5.21 (s, 1H), 4.77 (d, *J* = 1.5 Hz, 1H), 4.22 (dq, *J* = 10.4, 7.1 Hz, 1H), 4.05 (d, *J* = 13.9 Hz, 1H), 3.98- 3.81 (m, 2H), 3.51 - 3.23 (m, 2H), 1.95 (s, 3H), 1.51 (s, 3H), 0.95 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, C_6D_6): 196.5 (C), 153.4 (C), 151.9 (C), 146.5 (C), 143.1 (C), 136.9 (CH), 136.5 (C),

135.5 (C), 129.5 (2xCH), 128.9 (2xCH), 128.5 (2xCH), 127.7 (3xCH), 124.3 (CH), 123.2 (CH), 122.4 (C), 121.9 (CH), 120.8 (CH), 116.7 (CH), 111.1 (C), 81.6 (C), 61.9 (CH_2), 54.5 (CH_2), 40.7 (CH_2), 20.8 (CH_3), 16.1 (CH_3), 13.5 (CH_3). ESI(+)-MS: m/z (%) = 543 (100) $[M+H]^+$. Anal. Calcd for $C_{31}H_{30}N_2O_5S$: C, 68.61; H, 5.57; N, 5.16. Found: C, 68.73; H, 5.56; N, 5.17.

*(E)-ethyl 5-((benzyl(tert-butoxycarbonyl)amino)methylene)-3-methyl-3'-oxospiro[cyclopent[2]ene-1,2'-indoline]-1'-carboxylate (**4f**).* To a N_2-flushed solution of ethyl 2-methyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1b** (49 mg, 0.2 mmol) and [IPrAu(NTf_2)] (8.7 mg, 0.01 mmol) in 3 mL of anhydrous dichloromethane, a solution of *tert*-butyl benzyl(propa-1,2-dien-1-yl)carbamate **2f** (45 mg, 0.2 mmol) in 1 mL of dichloromethane was added dropwise at -20° C. The reaction mixture was stirred for 1 h. Then another solution of *tert*-butyl benzyl(propa-1,2-dien-1-yl)carbamate **2f** (45 mg, 0.2 mmol) in 1 mL of dichloromethane was added dropwise at -20° C. The reaction was stirred for 1 h, then quenched with PPh_3 and the solvent was removed under vacuum. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 9:1 to 8:2) yielded **4f** (70 mg, 72%) as yellow thick wax. ^1H NMR (300 MHz, C_6D_6): 8.67 (bs, 1H), 7.81 (dd, *J* = 7.6, 0.7 Hz, 1H), 7.39 - 7.03 (m, 6H, overlapping with the signal of C_6D_6), 6.78 (t, *J* = 7.2 Hz, 1H), 6.60 (bs, 1H), 4.92 (d, *J* = 1.4 Hz, 1H), 4.67 (bs, 2H), 4.23 - 3.91 (m, 2H), 3.28 - 2.94 (m, 2H), 1.61 (d, *J* = 0.9 Hz, 3H), 1.36 (s, 9H), 0.93 (t, *J* = 7.0 Hz, 3H). $^{13}C\{^1H\}$ NMR (75 MHz, C_6D_6): 197.6 (C), 153.3 (C), 151.8 (C), 145.4 (C), 139.1 (C), 136.8 (CH), 128.4 (2xCH), 127.0 (3xCH), 124.5 (CH), 123.1 (CH), 123.0 (CH), 122.6 (CH), 122.5 (C), 116.7 (CH), 80.4 (C), 61.3 (CH_2), 49.4 (CH_2), 40.2 (CH_2), 29.9 (C) 27.8 (3xCH_3), 16.3 (CH_3), 13.8 (CH_3). Two quaternary carbons are missing, probably overlapping with C_6D_6. ESI(+)-MS: m/z (%) = 511 (100) $[M+Na]^+$. Anal. Calcd for $C_{29}H_{32}N_2O_5$: C, 71.29; H, 6.60; N, 5.73. Found: C, 71.47; H, 6.61; N, 5.72.

*(E)-ethyl 3,5'-dimethyl-3'-oxo-5-((2-oxooxazolidin-3-yl)methylene)spiro[cyclopent[2]ene-1,2'-indoline]-1'-carboxylate (**4g**).* General procedure was followed using ethyl 2,7-dimethyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1c** (52 mg, 0.2 mmol), 3-(propa-1,2-dien-1-yl)oxazolidin-2-one **2a** (38 mg, 0.3 mmol) and [IPrAu(NTf_2)] (8.7 mg, 0.01 mmol) in anhydrous dichloromethane (3+1 mL) at -20° C for 1 h. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 3:1 to 1:1) yielded

4g (43 mg, 56%) as yellowish wax. ^{1}H NMR (300 MHz, C_6D_6): 8.42 (bs, 1H), 7.63 (s, 1H), 7.15 (dd, *J* = 8.7, 1.7 Hz, 1H), 6.50 (s, 1H), 5.01 (s, 1H), 4.18 (q, *J* = 7.1 Hz, 2H), 3.39 - 3.25 (m, 2H), 3.2 - 3.08 (m, 2H), 2.90 - 2.78 (m, 1H), 2.75 - 2.64 (m, 1H), 2.02 (s, 3H), 1.80 (s, 3H), 1.07 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, C_6D_6): 198.1 (C), 155.4 (C), 151.6 (C), 151.2 (C), 145.2 (C), 138.3 (CH), 133.1 (C), 124.5 (CH), 123.5 (CH), 122.4 (C), 118.4 (CH), 116.6 (CH), 83.0 (C), 61.5 (CH_2), 61.2 (CH_2), 43.4 (CH_2), 40.0 (CH_2), 20.1 (CH_3), 16.5 (CH_3), 14.0 (CH_3). One quaternary carbon is missing, probably overlapping with C_6D_6. ESI(+)-MS: m/z (%) = 405 (100) $[M+Na]^+$. Anal. Calcd for $C_{21}H_{22}N_2O_5$: C, 65.96; H, 5.80; N, 7.33. Found: C, 65.84; H, 5.79; N, 7.34.

*(E)-ethyl 5-((N-benzyl-4-methylphenylsulfonamido)methylene)-3,5'-dimethyl-3'-oxospiro[cyclopent[2]ene-1,2'-indoline]-1'-carboxylate (**4h**).* To a N_2-flushed solution of ethyl 2,7-dimethyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1c** (52 mg, 0.2 mmol) and [IPrAu(NTf_2)] (8.7 mg, 0.01 mmol) in 3 mL of anhydrous dichloromethane, a solution of *N*-benzyl-4-methyl-*N*-(propa-1,2-dien-1-yl)benzenesulfonamide **2e** (90 mg, 0.30 mmol) in 1 mL of dichloromethane was added dropwise in 12 h with the syringe pump at -20° C. The reaction mixture was stirred for 18 h. Then the reaction was quenched with PPh_3 and the solvent was removed under vacuum. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 9:1 to 8:2) yielded **4h** (65 mg, 60%) as yellow thick oil. ^{1}H NMR (300 MHz, C_6D_6): 8.53 (bs, 1H), 7.67 (d, *J* = 8.2 Hz, 2H), 7.48 (s, 1H), 7.21 - 7.04 (m, 4H overlapping with the signal of C_6D_6), 7.04 - 6.92 (m, 2H), 6.83 (d, *J* = 8.1 Hz, 2H), 5.10 (s, 1H), 4.67 (d, *J* = 1.5 Hz, 1H), 4.09 (dq, *J* = 10.4, 7.1 Hz, 1H), 3.95 (d, *J* = 13.9 Hz, 1H), 3.89 - 3.70 (m, 2H), 3.35 - 3.10 (m, 2H), 1.85 (s, 3H), 1.80 (s, 3H), 1.38 (d, *J* = 1.0 Hz, 3H), 0.82 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, C_6D_6): 196.3 (C), 151.7 (C), 151.4 (C), 146.1 (C), 142.9 (C), 137.8 (CH), 136.4 (C), 135.5 (C), 132.7 (C), 129.4 (2xCH), 128.7 (2xCH), 128.3 (2xCH), 127.5 (2xCH), 127.5 (CH), 124.0 (CH), 122.4 (C), 122.0 (CH), 120.6 (CH), 116.3 (CH), 81.7 (C), 61.6 (CH_2), 54.4 (CH_2), 40.5 (CH_2), 20.6 (CH_3), 19.9 (CH_3), 16.0 (CH_3), 13.3 (CH_3). One quaternary carbon is missing, probably overlapping with C_6D_6. ESI(+)-MS: m/z (%) = 579 (100) $[M+Na]^+$. Anal. Calcd for $C_{32}H_{32}N_2O_5S$: C, 69.04; H, 5.79; N, 5.03. Found: C, 68.97; H, 5.80; N, 5.04.

*(E)-ethyl 5'-methoxy-3-methyl-3'-oxo-5-((2-oxooxazolidin-3-yl)methylene)spiro[cyclopent[2]ene-1,2'-indoline]-1'-carboxylate (**4i**).* General procedure was followed using ethyl 7-methoxy-2-methyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1e** (55 mg, 0.2 mmol), 3-(propa-1,2-dien-1-yl)oxazolidin-2-one **2a** (38 mg, 0.3 mmol) and [IPrAu(NTf_2)] (8.7 mg, 0.01 mmol) in anhydrous dichloromethane (3+1 mL) at -20° C for 3 h. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 1:1) yielded **4i** (35 mg, 44%) as yellowish wax. ^{1}H NMR (300 MHz, C_6D_6): 8.32 (bs, 1H), 7.14 (d, *J* = 2.8 Hz, 1H), 7.01 (dd, *J* = 9.1, 2.9 Hz, 1H), 6.45 (bs, 1H), 4.89 (bs, 1H), 4.01 (q, *J* = 7.1 Hz, 2H), 3.15-2.92 (m, 7H), 2.64 (m, 1H), 2.47 (m, 1H), 1.65 (s, 3H), 0.89 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, C_6D_6): 198.1 (C), 156.5 (C), 155.3 (C), 151.4 (C), 147.7 (C), 144.7 (C), 126.3 (CH), 124.0 (C), 123.5 (CH), 122.8 (C), 118.4 (CH), 118.0 (CH), 105.2 (CH), 83.1 (C), 61.3 (CH_2), 60.9 (CH_2), 54.7 (CH_3), 43.1 (CH_2), 39.9 (CH_2), 16.4 (CH_3), 13.9 (CH_3). ESI(+)-MS**:** m/z (%) = 399 (100) $[M+H]^+$. Anal. Calcd for $C_{21}H_{22}N_2O_6$: C, 63.31; H, 5.57; N, 7.03. Found: C, 62.91; H, 5.58; N, 7,05.

*(E)-ethyl 5-((N-benzyl-4-methylphenylsulfonamido)methylene)-5'-fluoro-3-methyl-3'-oxospiro[cyclopent[2]ene-1,2'-indoline]-1'-carboxylate (**4j**).* General procedure was followed using ethyl 7-fluoro-2-dimethyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1d** (52 mg, 0.2 mmol), *N*-benzyl-4-methyl-*N*-(propa-1,2-dien-1-yl)benzenesulfonamide **2e** (90 mg, 0.3 mmol) [IPrAu(NTf_2)] (8.7 mg, 0.01 mmol) in anhydrous dichloromethane (3+1 mL) at -20° C for 18 h. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 9:1 to 8:2) yielded **4j** (55 mg, 45%) as yellow thick oil. ^{1}H NMR (300 MHz, C_6D_6): 8.51 (bs, 1H), 7.77 (d, *J* = 8.2 Hz, 2H), 7.41 (dd, *J* = 6.8, 2.8 Hz, 1H), 7.31 - 7.19 (m, 4H), 7.12 (m, 1H), 7.00 - 6.87 (m, 3H), 5.19 (s, 1H), 4.76 (d, *J* = 1.5 Hz, 1H), 4.26 - 3.80 (m, 4H), 3.46 - 3.22 (m, 2H), 1.96 (s, 3H), 1.52 (d, *J* = 0.9 Hz, 3H), 0.94 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, C_6D_6): 195.8 (C), 158.9 (d, *J* = 245 Hz, C), 151.8 (C), 149.6 (C), 146.8 (C), 143.2 (C), 136.4 (C), 135.4 (C), 129.6 (2xCH), 128.8 (2xCH), 128.5 (2xCH), 127.7 (CH), 127.6 (2xCH), 124.1 (d, *J* = 24.0 Hz, CH), 123.3 (d, *J* = 7.0 Hz, C), 121.6 (CH), 120.9 (CH), 118.0 (d, *J* = 7.2 Hz, CH), 111.1 (C), 109.6 (d, *J* = 22.9 Hz, CH), 82.1 (C), 62.0 (CH_2), 54.5 (CH_2), 40.6 (CH_2),

20.8 (CH_3), 16.1 (CH_3), 13.5 (CH_3). ESI(+)-MS: m/z (%) = 561 (100) $[M+H]^+$; Anal. Calcd for $C_{31}H_{29}FN_2O_5S$: C, 66.41; H, 5.21; N, 5.00. Found: C, 66.31; H, 5.20; N, 4.99.

*(E)-ethyl-6'-fluoro-3-methyl-3'-oxo-5-((2-oxooxazolidin-3-yl)methylene)spiro[cyclopentane-1,2'-indolin]-2-ene-1'-carboxylate (**4k**).* General procedure was followed using ethyl 6-fluoro-2-methyl-4*H*-furo[3,2-b]indole-4-carboxylate **1h** (52.2 mg, 0.2 mmol), 3-(propa-1,2-dien-1-yl)oxazolidin-2-one **2a** (38 mg, 0.3 mmol) and [IPrAu(NTf_2)] (8.7 mg, 0.01 mmol) in anhydrous dichloromethane (3+1 mL) at -20° C for 3 h. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 1:1) yielded **4k** (40 mg, 52%) as white wax. ^{1}H NMR (300 MHz, $CDCl_3$): 7.85 (bs, 1H), 7.74 (dd, *J* = 8.5, 5.8 Hz, 1H), 6.89 (td, *J* = 8.5, 2.2 Hz, 1H), 6.17 (t, *J* = 2.1 Hz, 1H), 5.16 (d, *J* = 1.5 Hz, 1H), 4.39 (t, *J* = 8.0 Hz, 2H), 4.28 (m, 2H), 4.08 (m, 2H), 3.44 (s, 2H), 1.94 (s, 3H), 1.31 (m, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 197.2 (C), 169.0 (d, *J* = 257 Hz, C), 156.0 (C), 151.3 (C), 146.7 (C), 145.3 (C), 127.1 (d, *J* = 12.2 Hz, CH), 122.9 (C), 122.4 (CH), 118.9 (CH), 118.3 (C), 111.9 1 (d, *J* = 25.2 Hz, CH) , 104.5 1 (d, *J* = 28 Hz, CH), 83.5 (C), 62.3 (CH_2), 62.1 (CH_2), 44.2 (CH_2), 40.0 (CH_2), 16.9 (CH_3), 14.3 (CH_3). ESI(+)-MS: m/z (%) = 387 (100) $[M+H]^+$; Anal. Calcd for $C_{20}H_{19}FN_2O_5$: C, 62.17; H, 4.96; N, 7.25. Found: C, 62.33; H, 4.94; N, 7.23.

*(E)-ethyl-5-(((N-benzyl-4-methylphenyl)sulfonamido)methylene)-6'-fluoro-3-methyl-3'-oxospiro[cyclopentane-1,2'-indolin]-2-ene-1'-carboxylate (**4l**).* General procedure was followed using ethyl 6-fluoro-2-dimethyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1h** (52 mg, 0.2 mmol), *N*-benzyl-4-methyl-*N*-(propa-1,2-dien-1-yl)benzenesulfonamide **2e** (90 mg, 0.3 mmol) [IPrAu(NTf_2)] (8.7 mg, 0.01 mmol) in anhydrous dichloromethane (3+1 mL) at -20° C for 24 h. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 9:1 to 8:2) yielded **4l** (73 mg, 65%) as yellow thick oil. ^{1}H NMR (300 MHz, $CDCl_3$):7.94 (d, *J* = 9.9 Hz, 1H), 7.71 (dd, *J* = 8.5, 5.7 Hz, 1H), 7.55 (d, *J* = 8.3 Hz, 2H), 7.40 – 7.11 (m, 7H), 6.86 (td, *J* = 8.5, 2.2 Hz, 1H), 5.04 (d, *J* = 1.5 Hz, 2H), 4.27 – 4.04 (m, 3H), 3.74 (bs, 1H), 3.26 – 2.97 (m, 2H), 2.39 (s, 3H), 1.81 (d, *J* = 1.2 Hz, 3H), 1.04 (t, *J* = 6.9 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$): 195.5 (C), 168.8 (d, *J* = 257 Hz, C), 154.7 (d, *J* = 14.1 Hz, C), 151.5 (C), 147.32 (C), 143.74 (C), 135.88 (C), 134.54 (C), 129.7 (2xCH), 128.47 (2xCH), 128.37

(2xCH), 127.78 (CH), 127.33 (2xCH), 126.62 (d, J = 11.8 Hz, CH), 121.29 (CH), 120.70 (CH), 118.21 (C), 111.58 (d, J = 24.4 Hz, CH), 104.14 (d, J = 29.2 Hz, CH), 82.20 (C), 62.26 (CH_2), 54.08 (CH_2), 40.34 (CH_2), 21.49 (CH_3), 16.73 (CH_3), 13.64 (CH_3). One quaternary carbon is missing, probably overlapped. ESI(+)-MS: m/z (%) = 561 (100) $[M+H]^+$. Anal. Calcd for $C_{31}H_{29}FN_2O_5S$: C, 66.41; H, 5.21; N, 5.00. Found: C, 66.52; H, 5.21; N, 4.38.

*Ethyl (R,E)-5-(((R)-4-benzyl-2-oxooxazolidin-3-yl)methylene)-3-methyl-3'-oxospiro[cyclopentane-1,2'-indolin]-2-ene-1'-carboxylate (**4m**).* To a N_2-flushed solution of 2-methyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1b** (49 mg, 0.2 mmol) and [IPrAu(NTf_2)] (8.7 mg, 0.01 mmol) in 3 mL of anhydrous dichloromethane, a solution of (*R*)-4-benzyl-3-(2l5-propa-1,2-dien-1-yl)oxazolidin-2-one **2g** (65 mg, 0.3 mmol) in 1 mL of dichloromethane was added dropwise in 12 h with the syringe pump at -20° C. The reaction mixture was stirred for 18 h. Then the reaction was quenched with PPh_3 and the solvent was removed under vacuum. Purification by flash chromatography (SiO_2, toluene/ethyl acetate 3:1) yielded **4m** (45 mg, 49%, *dr* = 13:1) as clear thick oil. Given data refers to major isomer. ^{1}H NMR (500 MHz, $CDCl_3$): 7.88 (dt, J = 8.2, 0.8 Hz, 1H), 7.39-7.24 (m, 4 H), 7.23-7.16 (m, 2H), 7.12 -7.06 (m, 2H), 6.12 (t, J = 1.5 Hz, 1H), 5.21 (m, 1H), 4.46 (q, J = 7.1 Hz, 2H), 3.72 (dd, J = 8.6, 3.4 Hz, 1H), 3.62 (m, 1H), 3.51 (m, 1H), 3.44 (m, 1H), 3.33 (dd, J = 20.2, 1.0 Hz, 1H), 2.98 (dd, J = 13.4, 4.0 Hz, 1H), 2.38 (m, 1H), 1.95 (d, J = 1.3 Hz, 3H), 1.45 (t, J = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): 174.9 (C), 155.8 (C), 150.8 (C), 144.3 (C), 140.8 (C), 138.7 (C), 135.5 (C), 129.7 (C), 129.1 (2xCH), 128.84 (2xCH), 128.76 (CH), 127.1 (CH), 126.2 (CH), 125.0 (CH), 124.6 (CH), 118.2 (CH), 114.8 (CH), 66.2 (CH_2), 64.1 (C), 63.5 (CH_2), 58.9 (CH), 43.0 (CH_2), 37.5 (CH_2), 16.6 (CH_3), 14.2 (CH_3). ESI(+)-MS: m/z(%) = 459 (100) $[M+H]^+$; Anal. Calcd for $C_{27}H_{26}N_2O_5$: C, 70.73; H, 5.72; N, 6.11. Found: C, 70.94; H, 5.71; N, 6.09.

General Procedure for the Synthesis of Compounds 3a-f. To a N_2-flushed solution of appropriate ethyl 4*H*-furo[3,2-*b*]indole-4-carboxylate **1a,f,g** (1.2 equiv.) and $(ArO)_3PAu(NTf_2)$ (5 mol%) in anhydrous toluene and in the presence of 200 mg of 4 Å MS, a solution of the appropriate *N*-allenamide **2a-d** (1.0 equiv.) in toluene was added dropwise at -20 °C. The reaction mixture was

stirred for 15 minutes, quenched with PPh_3 (15 mol%) and filtered through a pad of celite. The crude was purified by flash chromatography to yield the corresponding hydroarylated product **3a-f**.

*(E)-ethyl 2-(3-(2-oxooxazolidin-3-yl)allyl)-4H-furo[3,2-b]indole-4-carboxylate (**3a**).* General procedure was followed using ethyl 4*H*-furo[3,2-*b*]indole-4-carboxylate **1a** (55 mg, 0.24 mmol), 3-(propa-1,2-dien-1-yl)oxazolidin-2-one **2a** (25 mg, 0.2 mmol), $(ArO)_3PAu(NTf_2)$ (11 mg, 0.05 mmol) in anhydrous toluene (3+1 mL) at -20° C. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 2:1) yielded **3a** (64 mg, 90%), as a pink solid (m.p. 139.5-141° C). ^{1}H NMR (300 MHz, CD_2Cl_2): 8.31 (bs, 1H), 7.64 (m, 1H), 7.37 - 7.21 (m, 2H), 6.88 (d, *J* = 14.2 Hz, 1H), 6.58 (s, 1H), 5.07 (dt, *J* = 14.2, 7.1 Hz, 1H), 4.56 - 4.34 (m, 4H), 3.79 - 3.65 (m, 2H), 3.63 (d, *J* = 7.1 Hz, 2H), 1.52 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, CD_2Cl_2): 158.5 (C), 155.2 (C), 151.0 (C), 141.9 (C), 138.0 (C), 130.2 (C), 126.3 (CH), 123.3 (CH), 123.2 (CH), 118.0 (C), 116.1 (CH), 115.7 (CH), 105.5 (CH), 99.2 (CH), 63.1 (CH_2), 62.3 (CH_2), 42.5 (CH_2), 29.8 (CH_2), 14.2 (CH_3). EI-MS: m/z(%) = 354 (100) $[M]^+$. Anal. Calcd for $C_{19}H_{18}N_2O_5$: C, 64.40; H, 5.12; N, 7.91. Found: C, 64.63; H, 5.13; N, 7.92.

*(E)-ethyl 2-(3-(2-oxopyrrolidin-1-yl)allyl)-4H-furo[3,2-b]indole-4-carboxylate (**3b**).* General procedure was followed using ethyl 4*H*-furo[3,2-*b*]indole-4-carboxylate **1a** (55 mg, 0.24 mmol), 1-(propa-1,2-dien-1-yl)pyrrolidin-2-one **2b** (25 mg, 0.2 mmol), $(ArO)_3PAu(NTf_2)$ (11 mg, 0.05 mmol) in anhydrous toluene (3+1 mL) at -20° C. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 2:1) yielded **3b** (58 mg, 80%), as a pink solid (m.p. 141.4-142.9° C). ^{1}H NMR (300 MHz, CD_2Cl_2): 8.31 (bs, 1H), 7.63 (m, 1H), 7.35 - 7.26 (m, 2H), 7.09 (d, *J* = 14.4 Hz, 1H), 6.57 (s, 1H), 5.17 (dt, *J* = 14.3, 7.1 Hz, 1H), 4.53 (q, *J* = 7.1 Hz, 2H), 3.63 (d, *J* = 7.1 Hz, 2H), 3.55 (dd, *J* = 8.8, 5.6 Hz, 2H), 2.47 (t, *J* = 8.1 Hz, 2H), 2.18 - 2.06 (m, 2H), 1.52 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, CD_2Cl_2): 172.9 (C), 158.9 (C), 151.0 (C), 141.9 (C), 138.0 (C), 130.3 (C), 126.0 (CH), 123.2 (2xCH), 118.1 (C), 116.1 (CH), 115.7 (CH), 106.1 (CH), 99.2 (CH), 63.1 (CH_2), 45.2 (CH_2), 31.1 (CH_2), 30.2 (CH_2), 17.5 (CH_2), 14.2 (CH_3). ESI(+)-MS: m/z(%) = 576 (100) $[M+Na]^+$. Anal. Calcd for $C_{20}H_{20}N_2O_4$: C, 65.96; H, 5.80; N, 7.33. Found: C, 65.84; H, 5.79; N, 7.34.

*(E)-ethyl 2-(3-(N,4-dimethylphenylsulfonamido)allyl)-4H-furo[3,2-b]indole-4-carboxylate (**3c**).* General procedure was followed using ethyl 4*H*-furo[3,2-*b*]indole-4-carboxylate **1a** (55 mg, 0.24 mmol), *N*,4-dimethyl-*N*-(propa-1,2-dien-1-yl)benzenesulfonamide **2c** (45 mg, 0.2 mmol), $(ArO)_3PAu(NTf_2)$ (11 mg, 0.05 mmol) in anhydrous toluene (6+4 mL) at -20° C. The reaction mixture was stirred for 1 h. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 95:5) yielded **3c** (66 mg, 61%), as a wax. ^{1}H NMR (300 MHz, CD_2Cl_2): 8.31 (bs, 1H), 7.73 - 7.60 (m, 3H), 7.39-7.27 (m, 4H), 6.99 (d, *J* = 14.0 Hz, 1H), 6.52 (s, 1H), 4.96 (dt, *J* = 14.1, 7.1 Hz, 1H), 4.53 (q, *J* = 7.1 Hz, 2H), 3.58 (d, *J* = 7.1 Hz, 2H), 2.91 (s, 3H), 2.44 (s, 3H), 1.52 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, CD_2Cl_2): 158.7 (C), 151.0 (C), 144.1 (C), 141.9 (C), 137.9 (C), 134.5 (C), 130.3 (CH), 129.7 (2xCH), 127.0 (2xCH), 123.3 (CH), 123.2 (CH), 118.0 (C), 116.2 (CH), 115.6 (CH), 105.9 (CH), 99.1 (CH), 63.1 (CH_2), 32.3 (CH_3), 29.7 (CH_2), 21.2 (CH_3), 14.2 (CH_3). One quaternary carbon is missing, probably overlapped. ESI(+)-MS: m/z(%) = 453 (100) $[M+H]^+$. Anal. Calcd for $C_{24}H_{24}N_2O_5S$: C, 63.70; H, 5.35; N, 6.19. Found: C, 63.62; H, 5.36; N, 6.18.

*(E)-ethyl-2-(3-(4-methyl-N-phenylphenylsulfonamido)allyl)-4H-furo[3,2-b]indole-4-carboxylate (**3d**).* General procedure was followed using ethyl 4*H*-furo[3,2-*b*]indole-4-carboxylate **1a** (55 mg, 0.24 mmol), 4-methyl-*N*-phenyl-*N*-(propa-1,2-dien-1-yl)benzenesulfonamide **2d** (57 mg, 0.2 mmol), $(ArO)_3PAu(NTf_2)$ (11 mg, 0.05 mmol) in anhydrous toluene (6+4 mL) at -20° C. The reaction mixture was stirred for 1 h. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 95:5) yielded **3d** (62 mg, 60%), as a pink solid (m.p. 148.5-151°C). ^{1}H NMR (300 MHz, CD_2Cl_2): 8.27 (bs, 1H), 7.62-7.54 (m, 3H), 7.43 - 7.24 (m, 7H), 7.18 (dt, *J* = 13.9, 1.2 Hz, 1H), 7.08 - 6.95 (m, 2H), 6.40 (s, 1H), 4.63 - 4.42 (m, 3H), 3.49 (d, *J* = 7.2 Hz, 2H), 2.45 (s, 3H), 1.48 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (75 MHz, CD_2Cl_2): 158.4 (C), 151.0 (C), 144.1 (C), 141.8 (C), 137.9 (C), 136.7 (C), 135.8 (C), 131.3 (CH), 130.1 (2xCH), 129.6 (2xCH), 129.4 (2xCH), 128.9 (CH), 127.4 (2xCH), 123.2 (CH), 123.2 (CH), 118.0 (C), 116.1 (CH), 115.6 (CH), 107.0 (CH), 99.1 (CH), 63.0 (CH_2), 29.7 (CH_2), 21.3 (CH_3), 14.2 (CH_3). One quaternary carbon is missing, probably overlapped. ESI(+)-MS: m/z(%) =

537 (100) $[M+Na]^+$. Anal. Calcd for $C_{29}H_{26}N_2O_5S$: C, 67.69; H, 5.09; N, 5.44. Found: C, 67.53; H, 5.08; N, 5.45.

(E)-ethyl 7-methyl-2-(3-(2-oxooxazolidin-3-yl)allyl)-4H-furo[3,2-b]indole-4-carboxylate ***(3e)***. General procedure was followed using ethyl 7-methyl-4*H*-furo[3,2-*b*]indole-4-carboxylate **1f** (58 mg, 0.24 mmol), 3-(propa-1,2-dien-1-yl)oxazolidin-2-one **2a** (25 mg, 0.2 mmol), $(ArO)_3PAu(NTf_2)$ (11 mg, 0.05 mmol) in anhydrous toluene (3+1 mL) at -20° C. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 2:1) yielded **3e** (52 mg, 70%), as a pink solid (m.p. 121.2-122.7° C). ^1H NMR (300 MHz, CD_2Cl_2): 8.17 (bs, 1H), 7.43 (s, 1H), 7.12 (dd, *J* = 8.5, 1.1 Hz, 1H).), 6.87 (d, *J* = 14.2 Hz, 1H), 6.56 (s, 1H), 5.06 (dt, *J* = 14.2, 7.1 Hz, 1H), 4.56 - 4.41 (m, 4H), 3.75 (dd, *J* = 8.9, 7.2 Hz, 2H), 3.62 (d, *J* = 7.1 Hz, 2H), 2.49 (s, 3H), 1.51 (t, *J* = 7.1 Hz, 3H). $^{13}C\{^1H\}$ NMR (75 MHz, CD_2Cl_2): 158.3 (C), 155.2 (C), 151.0 (C), 141.8 (C), 136.2 (C), 133.0 (C), 126.2 (CH), 124.4 (CH), 118.1 (C), 115.7 (2xCH), 105.5 (CH), 99.2 (CH), 62.9 (CH_2), 62.3 (CH_2), 42.5 (CH_2), 29.8 (CH_2), 21.0 (CH_3), 14.2 (CH_3). One quaternary carbon is missing, probably overlapped. ESI(+)-MS: m/z(%) = 391 (100) $[M+Na]^+$. Anal. Calcd for $C_{20}H_{20}N_2O_5$: C, 65.21; H, 5.47; N, 7.60. Found: C, 65.33; H, 5.49; N, 7.58.

(E)-ethyl 7-fluoro-2-(3-(2-oxooxazolidin-3-yl)allyl)-4H-furo[3,2-b]indole-4-carboxylate ***(3f)***. General procedure was followed using ethyl 7-fluoro-4*H*-furo[3,2-*b*]indole-4-carboxylate **1g** (59 mg, 0.24 mmol), 3-(propa-1,2-dien-1-yl)oxazolidin-2-one **2a** (25 mg, 0.2 mmol), $(ArO)_3PAu(NTf_2)$ (11 mg, 0.05 mmol) in anhydrous toluene (3+1 mL) at -20° C. Purification by flash chromatography (SiO_2, hexane/ethyl acetate 4:1) yielded **3f** (71 mg, 95%), as a pink solid (m.p. 172.6-173.1° C). ^1H NMR (300 MHz, CD_2Cl_2): 8.24 (s, 1H), 7.28 (m, 1H), 6.99 (td, *J* = 9.2, 2.7 Hz, 1H), 6.85 (d, *J* = 14.3 Hz, 1H), 6.54 (s, 1H), 5.03 (dt, *J* = 14.2, 7.1 Hz, 1H), 4.54 - 4.39 (m, 4H), 3.73 (dd, *J* = 8.9, 7.2 Hz, 2H), 3.64 - 3.57 (m, 2H), 1.49 (t, *J* = 7.1 Hz, 3H). $^{13}C\{^1H\}$ NMR (75 MHz, CD_2Cl_2): 159.5 (d, *J* = 239 Hz, C). 159.4 (C), 155.2 (C), 150.8 (C), 145.9 (C),134.2 (C), 126.4 (CH), 118.6 (d, *J* = 10.8 Hz, C), 117.1 (d, *J* = 9.4 Hz, CH), 110.2 (d, *J* = 24.9 Hz, CH), 105.2 (CH), 101.8 (d, *J* = 26.0 Hz, CH), 99.2 (CH), 63.2 (CH_2), 62.3 (CH_2), 42.5 (CH_2), 29.8 (CH_2), 14.2 (CH_3). One quaternary carbon is

missing, probably overlapped. ESI(+)-MS: m/z(%) = 395 (100) $[M+Na]^+$. Anal. Calcd for $C_{19}H_{17}FN_2O_5$: C, 61.29; H, 4.60; N, 7.52. Found: C, 61.24; H, 4.59; N, 7.53.

Preparation of products 5a, 5b and 6.

*(Z)-N-((1'-(ethoxycarbonyl)-3-methyl-3'-oxospiro[cyclopentane-1,2'-indoline]-2,4-dien-5-yl)methylene)-1-phenylmethanaminium hydroxide (**5a**)*. To solution of **4f** (62 mg, 0.13 mmol) in dichloromethane (1 ml) TFA (0.1 ml) was added dropwise at room temperature and the resulting mixture was stirred for 1 h at room temperature. Then it was quenched with 1M NaOH solution (10 ml) and extracted with dichloromethane (3 x 10 ml). Purification by flash chromatography (SiO_2, hexane/ethyl acetate 9:1) yielded **5a** (20 mg, 38%) as yellow thick oil. ^{1}H NMR (300 MHz, $CDCl_3$): 12.65 (bs, 1H), 8.66 (s, 1H), 8.20 (d, *J* = 8.2 Hz, 1H), 7.61 (d, *J* = 13.4 Hz, 1H), 7.55 (m, 1H), 7.49-7.34 (m, 6H), 7.08 (t, *J* = 7.3 Hz, 1H), 6.88 (s, 1H), 6.79 (s, 1H), 4.76 (d, *J* = 5.7 Hz, 2H), 4.20 (q, *J* = 7.1 Hz, 2H), 2.13 (s, 3H), 1.32 (m, 3H). $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$): 189.4 (C), 153.8 (C), 153.3 (CH), 141.2 (CH), 137.2 (C), 136.3 (C), 135.1 (CH), 130.8 (CH), 130.7 (2 x CH), 130.6 (C), 129.1 (2 x CH), 129.3 (C), 128.2 (CH), 127.5 (CH), 125.7 (C), 121.4 (CH), 120.1 (CH), 117.7 (C), 61.02 (CH_2), 53.35 (CH_2), 14.60 (CH_3), 14.23 (CH_3). ESI(+)-MS**:** m/z (%) = 411 (100) $[M+Na]^+$.

*(**5b**)*: To solution of **4h** (50 mg, 0.09 mmol) in dichloromethane (1 ml) TFA (0.1 ml) was added dropwise at room temperature and the resulting mixture was stirred for 5 h at room temperature. Then it was quenched with 1M NaOH solution (10 ml) and extracted with dichloromethane (3 x 10 ml). Purification by flash chromatography (SiO_2, toluene/ethyl acetate 98:2) yielded **5b** (16 mg, 31%) as yellow thick oil. ^{1}H NMR (300 MHz, $CDCl_3$): 9.55 (s, 1H), 9.05 (s, 1H), 8.15 (d, *J* = 8.5 Hz, 1H), 7.81 (d, *J* = 8.4 Hz, 2H), 7.41 (d, *J* = 1.7 Hz, 1H), 7.35-7.20 (m, 8H), 6.61 (d, *J* = 1.5 Hz, 1H), 6.22 (s, 1H), 5.10 (s, 2H), 4.21 (q, *J* = 7.1 Hz, 2H), 2.43 (s, 3H), 2.31 (s, 3H), 1.92 (s, 3H), 1.33 (t, *J* = 7.1 Hz, 3H). $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$): 193.8 (C), 154.0 (C), 145.2 (C), 142.7 (CH), 139.9 (C), 139.7 (CH), 136.7 (C), 135.4 (C), 134.9 (C), 134.2 (C), 133.1 (CH), 132.0 (CH), 130.5 (C), 130.2 (2 x CH), 128.9 (2 x CH), 127.7 (2 x CH), 127.6 (CH), 127.1 (C), 126.1 (2 x CH), 121.7 (CH), 120.4

(C), 120.0 (CH), 61.0 (CH_2), 51.5 (CH_2), 21.6 (CH_3), 20.7 (CH_3), 15.06 (CH_3)., 14.57 (CH_3). ESI(+)-MS**:** m/z (%) = 579 (100) $[M+Na]^+$.

*2-hydroxy-5'-methyl-3'-oxospiro[cyclopentane-1,2'-indoline]-2,4-diene-3,5-dicarbaldehyde (**6**).* To a suspension of **4g** (43 mg, 0.1 mmol) in 1,4-dioxane (0.4 ml) SeO_2 (27 mg, 0.25 mmol) was added and the mixture was stirred at 100 °C for 2.5 h. Then it was filtered over a pad of celite and concentrated in vacuum. Purification by flash chromatography (SiO_2hexane/ethyl acetate 3:1) yielded **6** (7 mg, 25%) as yellow thick oil. ^{1}H NMR (500 MHz, DMSO): 13.38 (s, 1H), 9.93 (s, 1H), 9.34 (s, 1H), 8.29 (m, 2H), 8.10 (s, 1H), 7.72 (d, *J* = 7.6 Hz, 1H), 2.53 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, DMSO): 185.3 (CH), 185.2 (CH), 160.8 (C), 144.4 (CH), 143.9 (C), 137.0 (C), 134.6 (CH), 134.2 (C), 122.7 (CH), 119.8 (CH), 118.9 (C), 116.5 (C), 115.8 (C), 113.4 (C) 21.33 (CH_3). ESI(-)-MS**:** m/z (%) = 252 (100) $[M-OH]^-$.

ASSOCIATED CONTENTS

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI:. NMR spectra of all synthesized compounds, 2D-NMR spectra of compound **4a, 4m**, **5a**, **6** and CCDC 1874486 (**3a**), 1874487 (**4a**) (PDF).

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The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. ‡These authors contributed equally.

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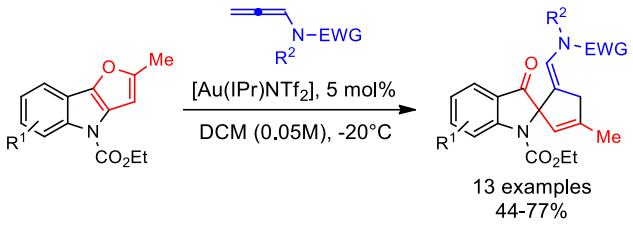
N–EWG
R2
Me
O
R1
N
CO2Et
[Au(IPr)NTf2], 5 mol%
DCM (0.05M), -20°C
R2
N–EWG
O
R1
N
Me
CO2Et
13 examples
44-77%