Synthesis of Functionalized 4-Chlorophthalates, 2-Naphthoates, 2-Fluorobiaryls, and Arylpyridines by Cyclocondensation Reactions of 1,3-Bis(silyloxy)-1,3-butadienes and Related Dienes and by Palladium(0)-Catalyzed Cross-Coupling Reactions

DISSERTATION

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Affectionately Dedicated to

My Parents

CONTENTS

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Abbreviations

Ar	Aromatic
APT	Attached Proton Test
ATCC	American Type Culture Collection
*n*BuLi	*n*-Butylithium
DEPT	Distortionless Enhancement by Polarisation Transfer
EI	Electronic Impact
ESI	Electrospray Ionization
EtOAc	Ethylacetate
HRMS	High Resolution Mass Spectroscopy
IR	Infrared Spectroscopy
LDA	Lithium Diisopropylamide
MS	Mass Spectrometry
Ph	Phenyl
NEt_3	Triethylamine
NMR	Nuclear Magnetic Resonance
HMQC	Heteronuclear Multiple Quantum Coherence
HMBC	Heteronuclear Multiple Bond Correlation
COSY	Correlated Spectroscopy
NOESY	Nuclear Overhauser and Exchange Spectroscopy
Me_3SiOTf	Trimethylsilyl-trifluoromethanesulfonate
Me_3SiCl	Trimethylsilylchloride
mp.	Melting Point
RCM	Ring Closing Metathesis
TBAI	Tetrabutyl Amonium Iodide
TBAF	Tetrabutyl Amonium Fluoride
TFA	Trifluoroacetic Acid
Tf_2O	Trifluoromethanesulfonic Anhydride
THF	Tetrahydrofurane
TLC	Thin Layer Chromatography
TMS	Trimethylsilane
UV	Ultraviolet Spectroscopy.

Summary

Some of the work mentioned here has been published earlier so some of the related part is taken from the publications. The thesis can be summarized as follows:

1. *Synthesis of highly functionalized biaryls by condensation of 2-fluoro-1,3-bis(silyloxy)-1,3-dienes with 3-cyanochromone sand subsequent domino ′retro-Michael / aldol / fragmentation′ reaction*. This chapter includes the synthesis of highly functionalized biaryls **6a-p** by condensation of 2-fluoro-1,3-bis(silyloxy)-1,3-dienes with 3-cyanochromones.

2 *Synthesis of 1,4-diaryl-2-naphthoates and 1,4-bis(alkynyl)-2-naphthoates based on site-selective Suzuki-Miyaura and Sonogoshira reactions.* This chapter includes the synthesis of a number of examples of diaryl- and bis(alkynyl)-naphthoates by palladium-catalyzed Suzuki and Sonogoshira coupling reactions. Using this methodology, I successfully synthesized products with very good site-selectivity.

3. *Synthesis of 3,5-diaryl-4-chlorophthalates by [4+2] cycloaddition of 1-ethoxy-2-chloro-1,3-bis(trimethylsilyloxy)-1,3-diene with dimethyl acetylenedicarboxylate and subsequent site-selective Suzuki-Miyaura reactions.* In this chapter, I have described the synthesis of 3,5-diaryl-4-chlorophthalates having the same or different aryl groups. I reported a convenient approach to dimethyl 4-chloro-3,5-dihydroxyphthalate. Suzuki-Miyaura reactions of the bis(triflate) of this dihydroxyphthalate proceed with very good site-selectivity.

4 *Synthesis of functionalized arylpyridines and arylpyrimidines based on a Diels-Alder approach.* This chapter includes the synthesis of various functionalized arylpyridines and pyrimidines by application of novel Diels-Alder reactions. Fifteen products were synthesized using five different pyridyl/pyrimidyl acetylenes as dienophiles, thus finding a simple method for the synthesis of molecules which can be of considerable pharmacological relevance.

6. This chapter includes the experimental, spectroscopic data and full characterization of all new products.

1. Synthesis of highly functionalized biaryls by condensation of 2-fluoro-1,3-bis(silyloxy)-1,3-dienes with 3-cyanochromones and subsequent domino ′retro-Michael / aldol / fragmentation′ reactions

1.1 Introduction:

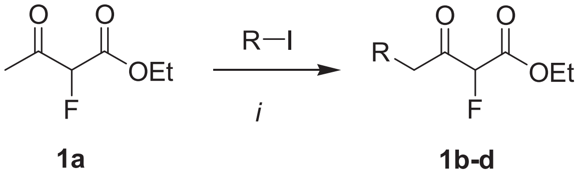
Organic compounds bearing fluorine atom have a special importance because of their medicinal potential.[1] This importance is attributed to the fact that the high electronegativity of fluorine with such a small size makes it beneficial for drug receptor interactions whereas the strength and stability of the carbon-fluorine bond helps to prevent its involvement in any side reactions. In addition to these remarkable characteristics, a special tribute goes to the lipophilicity of the fluorinated organic compounds which helps in the transport of the drug. In addition to their medicinal importance, fluorinated organic compounds also find their use as versatile building blocks in transition metal catalyzed coupling reactions (specially arenes and heteroarenes), as ligands,[3] or as organocatalysts.[4]

In order to develop new synthetic ways for many different kinds of heterocycles, our group has been working with the use of 1,3-bis(silyloxy)-1,3-butadienes and has been successful in many achievements related to that. Recently, studies were carried out related to the reaction of 1,3-bis(silyloxy)-1,3-butadienes with chromone derivatives.[5, 6] As a result of these studies, Langer *et al.* were able to report an efficient synthesis of azaxanthones by condensation of 1,3-bis(silyloxy)-1,3-butadienes with 3-cyanochromones and subsequent base-mediated domino[7] ′retro-Michael / nitrile-addition / heterocyclization′ reaction.[8] In addition, the Langer group also achieved the synthesis of biaryl lactones by condensation of 1,3-bis(silyloxy)-1,3-butadienes with chromones and subsequent base-mediated domino ′retro-Michael / aldol / lactonization′ reaction.[9] In my thesis, I have studied the reaction of 3-cyanochromones with 2-fluoro-1,3-bis(silyloxy)-1,3-dienes which give rise to the unexpected formation of highly functionalized fluorinated biaryls. The products are formed by a hitherto unprecedented domino ′retro-Michael / aldol / fragmentation′ reaction.

1.2 Results and discussion:

To carry out the proposed research on my project it was necessary to synthesize some 2-fluoro-3-oxoesters. An efficient synthesis of β-ketoesters involves the reaction of 1,3-dicarbonyl dianions with alkyl halides.[10] The application of this methodology to the synthesis of fluorinated derivatives has, to the best of my knowledge, not been reported to date. 2-

Fluoro-3-oxoesters **1b-d** were prepared, following a procedure developed by my colleagues M. Farooq and V. Wolf (dissertations, University of Rostock, in preparation), by reaction of the dianion of commercially available ethyl 2-fluoroacetoacetate (**1a**) with various alkyl iodides (Scheme 1, Table 1). The yields (59-62%) are typical for dianion reactions and the experiments thus show that the fluorine substituent is compatible with the reaction conditions.



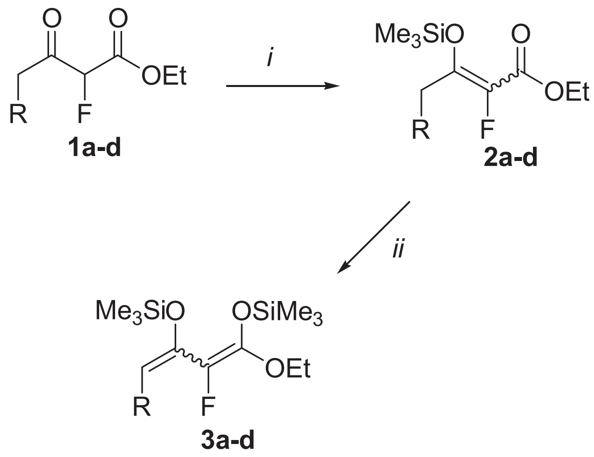
Scheme 1. Synthesis of **1b-d**: *i*: 1) LDA (2.3 equiv.), THF, –78 °C, 1 h; 2) R-I, –78 → 20 °C, 14 h; 3) HCl (10%).

Table 1. Synthesis of **1b-d**

1	R	% [a]
b	*n*Pr	59
c	*n*Oct	62
d	*n*Dec	61

[a] Yields of isolated products; products were prepared by M. Farooq and V. Wolf

Dienes **3a-d** were prepared again following the protocol developed by V. Wolf and M. Farooq. The 2-fluoro-3-oxoesters **1a-d** afforded silyl enol ethers **2a-d** upon silylation. Then, the synthesis of the respective 1-ethoxy-2-fluoro-1,3-bis(trimethylsilyloxy)-1,3-dienes **3a-d** involved deprotonation (LDA) at –78 °C and subsequent addition of trimethylchlorosilane (Scheme 2, Table 2). The synthesis of **3a** has been previously reported.[11] These dienes **3a-d** can be stored at –20 °C under inert atmosphere for several weeks.



Scheme 2. Synthesis of **3a-d**: *i*: Me$_3$SiCl, NEt$_3$, benzene, 20 °C, 48 h; *ii*: 1) LDA, THF, −78 °C, 1 h, 2) Me$_3$SiCl, −78 → 20 °C, 14 h; the geometry of the double bonds are not unambigiously assigned

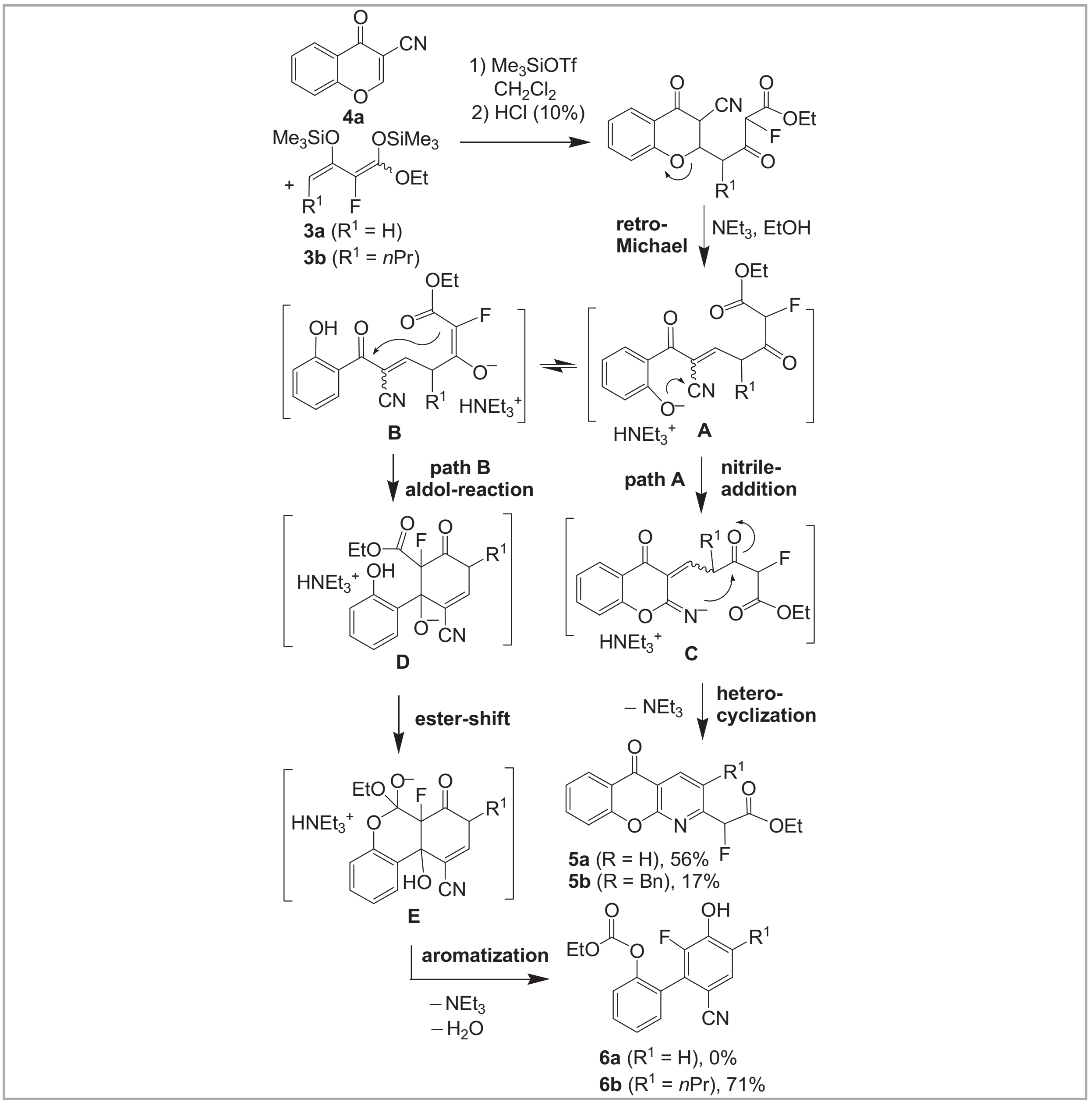
Table 2. Synthesis of **3a-d**

2,3	R	% (**2**) [a]	% (**3**) [a]
a	H	81	94
b	*n*Pr	82	90
c	*n*Oct	84	94
d	*n*Dec	81	92

[a] Yields of isolated products; products were prepared by M. Farooq and V. Wolf

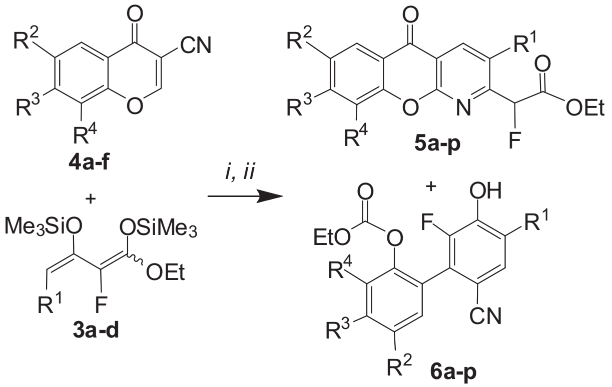
3-Cyano-2-(4-ethoxy-3-fluoro-2-4-dioxobutyl)chroman-4-one was obtained as a product when **3a** was treated with with 3-cyanochromone (**4a**). This product, upon reaction in ethanol with triethylamine, yielded fluorinated azaxanthone **5a** in 56% yield (Scheme 3). Its formation, which has been reported previously,[11] can be explained by a domino ′retro-Michael / nitrile-addition / heterocyclization′ reaction (path A). The retro-Michael reaction gave intermediate **A** which underwent a nitrile addition to give intermediate **C**. Heterocyclization of the latter afforded **5a**. However, when **4a** was reacted with diene **3b** then the result of this reaction was quite different and I obtained fluorinated biaryl **6b** (71% yield) (Scheme 3). The usually expected product azaxanthone **5b** was isolated in only 17% yield. The unusual formation of the new compound **6b** can be explained by a domino ′retro-

Michael / aldol / 1,5-ester-shift′ reaction (path B). A proton shift of intermediate **A** afforded **B** which underwent an intramolecular aldol reaction to give **D**. An intramolecular ester shift (intermediate **E**) followed by aromatization gave compound **6b**. This process is similar to the formation of biaryl lactones by condensation of 1,3-bis(silyloxy)-1,3-butadienes with simple chromones and subsequent base-mediated domino ′retro-Michael / aldol / lactonization′ reaction.[8] The option of a direct aromatization during the intramolecular aldol reaction seems to be impossible here because a quaternary carbon atom is involved. However, the aromatization can take place because of the fragmentation.



Scheme 3. Possible mechanisms of the formation of **5a** and **6b**

It was assumed that the chain length of the diene plays an important part in the distribution of the products. So I studied the reactions with different variations of both diene and of the chromone systematically (Scheme 4, Table 3). The products of the reaction of dienes **3b-d** with the parent 3-cyanochromone (**4a**) gave a clear discrimination in the products and mainly afforded the biaryls **6b-d**. Azaxanthones **5b-d** were isolated as side-products. The reaction of unsubstituted diene **3a** with 3-cyanochromone **4b**, containing two electron-donating methyl groups, exclusively afforded azaxanthone **5e**. In contrast, biaryl **6f** was the main products in the reaction of **4b** with substituted diene **3b**. In all the cases where the reaction was carried out with the unsbstituted diene **3a**, the products were exclusively azaxanthones. In contrast, fluorinated biaryls **6g-i**, **6k-m, 6o** and **6p** were formed in the reaction of **4c-f** with substituted dienes **3b-d**.



Scheme 4. Synthesis of **5a-p** and **6a-p**; *i*, 1) Me_3SiOTf, 1 h, 20 °C; 2) CH_2Cl_2, 0→20°C, 12h; 3) HCl (10%); *ii*, 1) NEt_3, EtOH, 20 °C, 12 h; 2) HCl (10%).

Table 3. Synthesis of **5a-p** and **6a-p**

3	4	5,6	R^1	R^2	R^3	R^4	% (**5**) [a,b]	% (**6**) [a]
a	**a**	**a**	H	H	H	H	56[b]	0
b	**a**	**b**	*n*Pr	H	H	H	17	71
c	**a**	**c**	*n*Oct	H	H	H	20	63
d	**a**	**d**	*n*Dec	H	H	H	13	76
a	**b**	**e**	H	Me	Me	H	46[b]	0
b	**b**	**f**	*n*Pr	Me	Me	H	14	71
d	**c**	**g**	*n*Dec	Me	H	Me	18	63
b	**d**	**h**	*n*Pr	Cl	H	H	13	73
c	**d**	**i**	*n*Oct	Cl	H	H	-	77
a	**e**	**j**	H	Cl	H	Cl	35[b]	0
b	**e**	**k**	*n*Pr	Cl	H	Cl	13	73
c	**e**	**l**	*n*Oct	Cl	H	Cl	21	63
d	**e**	**m**	*n*Dec	Cl	H	Cl	-	76
a	**f**	**n**	H	F	H	H	33[b]	0
b	**f**	**o**	*n*Pr	F	H	H	16	75
d	**f**	**p**	*n*Dec	F	H	H	-	77

[a] Yields of isolated products; [b] experiment carried out by Dr. Muhammad Adeel

1.3 Conclusion:

In this chapter I reported the Me_3SiOTf-mediated condensation of 1-ethoxy-2-fluoro-1,3-bis(trimethylsilyloxy)-1,3-dienes with 3-cyanochromones and the treatment of this intermediate with triethylamine to afford fluorinated azaxanthones or biaryls. In these reactions the use of unsubstituted diene **3a** generally resulted in exclusive formation of fluorinated azaxanthones **5** by a domino ′retro-Michael / nitrile-addition / heterocyclization′ reaction. However, when the reaction was carried out with the substituted dienes **3b-d** then the fluorinated biaryls were the main products. Their formation can be explained by an unprecedented domino ′retro-Michael / aldol / fragmentation′ reaction. In some reactions, the corresponding azaxanthones were isolated as side-products. Thus, the product distribution is influenced by the chain length of the diene. The steric influence of the fluorine atom and of the substituent R^1 may result in a conformation which facilitates the intramolecular aldol reaction at the expense of the nitrile addition.

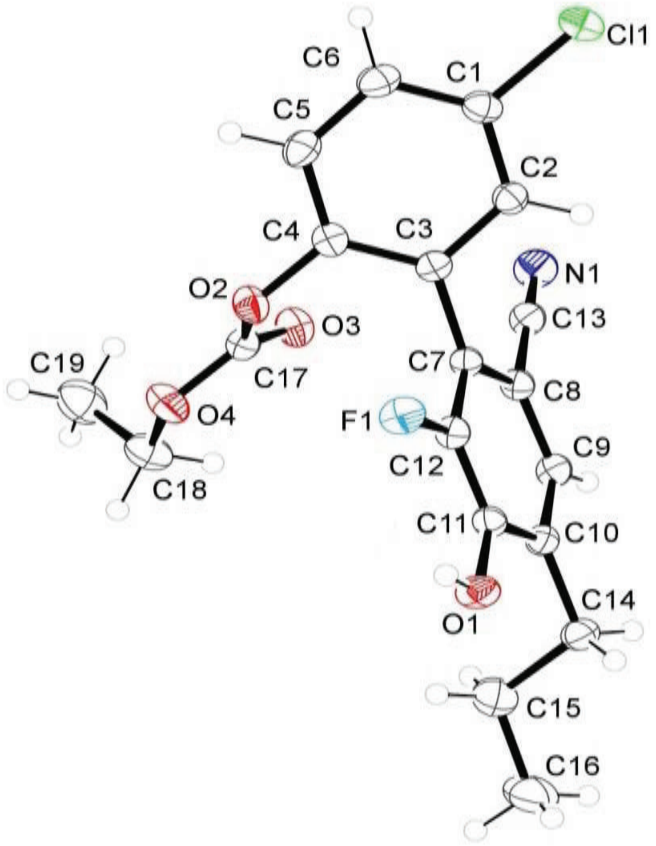


Figure 1: Ortep Plot of **6h**

2. Synthesis of 1,4-Diaryl-2-naphthoates and 1,4-Bis(alkynyl)-2-naphthoates based on Site-Selective Suzuki-Miyaura and Sonogoshira Reactions

2.1 General Introduction:

Chemists have always been interested in devising new methods for the formation of carbon-carbon bonds. These reactions very much facilitate the construction of complex molecules from simple precursors. The Grignard, Diels–Alder, and Wittig reaction have been of great use in this regard in the last century. But for the last three decades transition metal-catalyzed reactions, particularly palladium(0)-catalyzed transformations, have gained remarkable importance for carbon-carbon bond formation and many new ideas have been tested and realized.[12] Nowadays, these reactions are being used for the synthesis of a number of natural products, pharmaceuticals and advanced materials.[13-15] The most commonly applied palladium-catalyzed carbon–carbon bond forming reactions in total synthesis are, namely, the Heck[16], Stille[17], Suzuki[18], Sonogashira[19], Tsuji–Trost[20], and the Negishi[21] reaction. The mechanism of these reactions are similar. The first step is usually the oxidative addition of organic halides or triflates to the Pd(0) complex to form organopalladium halides. The following step is, in case of the Suzuki, Sonogashira and Stille reaction, often a transmetallation with nucleophilic compounds to give a diorganopalladium complex. This complex undergoes a reductive elimination to create carbon-carbon bond and regeneration of the catalyst.

Suzuki Reaction:

The Suzuki reaction is the reaction that gained much importance for its usefulness for the cross-coupling between halides and organoboronic acids.[22] Advances made in this field include the development of new catalysts and modern methods have greatly increased the scope of this reaction and is now considered to be a quite general procedure for a wide range of selective carbon-carbon bond formations.[23] The scope of the reaction partners is not restricted to arenes, but includes also alkyl, alkenyl and alkynyl compounds.

The mechanism of the Suzuki reaction involves the oxidative addition of organic halides or triflates to the Pd(0) complex to form a organopalladium halide (R^1-Pd(II)-X). This step is followed by transmetallation with a boronic acid derivative or a borane to give a diorganopalladium complex (R^1-Pd-R^2). This complex undergoes a reductive elimination with carbon-carbon bond formation and regeneration of the catalyst.[24-27] The reactivity order of aryl halides and aryl triflates, which act as electrophiles, is Ar-I > Ar-Br > Ar-OTf > Ar-Cl. The use of base accelerates the transmetalation. This is due to the increase of the carbanion character of the organoborane moiety by formation of an organoborate containing a tetravalent boron atom. The selection of a proper catalyst plays an important role in the success of the desired reaction. The common palladium sources employed include, for example, $Pd(OAc)_2$, $PdCl_2$, $Ph(PPh_3)_2Cl_2$, and $Pd(dba)_2$. The use of bulky electron-rich ligands is often the key for a successful transformation. The ferrocenylphosphine[28], *N*-heterocyclic carbenes,[29] $P(tBu)_3$[30], $P(Cy)_3$ often give a good yield.

Miyaura-Suzuki reactions[31], in particular, are very attractive, due to the stability of the precursors, boronic acids, and facility of work up. In this reaction even an alkyl group (i.e. sp^3-hybridized C atom), as opposed to the more traditionally used vinyl or aryl groups, can be transferred from the organoborane component during the palladium-catalyzed coupling process with vinyl or aryl halides or triflates. Compared to Stille reactions[32], Suzuki–Miyaura couplings have a much broader scope in that a potentially vast range of alkyl boranes (typically prepared through the regio- and chemoselective hydroboration of readily available alkene precursors) can be employed in the reaction.[33] The interest of the chemist in this field is evident from the continuous developments in the use of new reaction conditions, catalysts and ligands.[34-36]

Sonogoshira reaction:

One of the most useful and effective methods for the synthesis of substituted alkynes is the Sonogashira reaction that has been developed in the last quarter of the 20th century.[37] Substituted alkynes have also been synthesized by use of many other metal acetylides (e.g. Zn,[38] Mg,[39] B,[40] Al,[41] and Sn[42] derivatives) involving the palladium-catalyzed coupling. But owing to its extensive applicability and suitability, the Sonogashira protocol (employing cocatalytic Cu salts) is the most widely used method for alkynylation reactions. This method was reported for the first time in 1975 involving the use of Cu as cocatalyst.[43] There has been a lot of development in the protocol for Sonogashira reactions since then. Nowadays, the Sonogashira reaction can be carried out under mild conditions even at room temperature, with high turnover numbers. Modern variations enable it to carry out the reaction even in copper-free conditions. The reaction medium must be basic in order to neutralize the hydrogen halide produced as the byproduct of this coupling reaction. Thus, alkylamine compounds such as triethylamine and diethylamine are often used. Other bases such as potassium carbonate or cesium carbonate are occasionally used. As in the other Pd-catalyzed cross-coupling reactions, the general order of reactivity of organic electrophiles with respect to the leaving groups is vinyl iodide > vinyl triflate > vinyl bromide > aryl iodide > aryl triflate > aryl bromide >> aryl chloride; the use of aryl or vinyl iodides often results in a smooth Sonogashira reaction.[44]

The different mechanism of different variants of the Sonogashira reaction leads to different invidual protocols. The in situ generation of copper alkylides under the reaction conditions often generates homocoupling products (so-called Glaser coupling).[45] Many different protocols have been established for Sonogashira reactions. Typical reactions are performed using a palladium(0)-phosphane complex in the presence of a cocatalytic amount of a copper (I) salt and an amine (used as a solvent or in large excess) under homogeneous conditions. The catalysts that have been in use are triphenylphosphane-related complexes, such $Pd(PPh_3)_4$, $Pd(PPh_3)_2Cl_2$, $Pd(dppe)Cl_2$, $Pd(dppp)Cl_2$ or $Pd(dppf)Cl_2$. Usually in the reaction 5 mol% of palladium are used. Larger amounts of the copper(I) salt are often employed. Other palladium sources employed are $Pd(OAc)_2$, $Pd_2(PhCN)_2$, $Pd_2(CH_3CN)_2$, $Pd_2(dba)_3$[46] and $Pd(\eta^3\text{-}C_3H_5)Cl_2$[47], and ligands, such as, $P(t\text{-}Bu)_3$, $P(Cy)_3$, electron-rich o-biphenylphosphane (X-Phos),[48] multidentate ferrocenyl phosphanes, and tetraphosphanes.

In general, Sonogoshira reactions have a great importance in organic synthesis and have a number of applications in a variety of fields like synthesis of natural products,[49,50] of electronic and electrooptical[51-53] and of molecules for nanostructures.[54-56]

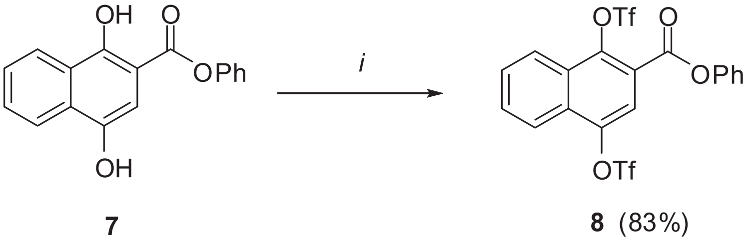
2.2 Introduction:

Naphthalene and its derivatives are found to act as intermediates in the synthesis of organic dyes, medicines, and surfactants. In the polymer industry they also serve in the function of supporting agents.[57] Naphthalene derivatives are found in a number of natural sources,[58,59] (examples are 4-hydroxy-3,5-dimethoxy-2-naphthaldehyde and 4-hydroxy-5-methoxy-2-naphthaldehye).[3] Naphthalene derivatives also exhibit marked pharmacological activities like antimicrobial activities[60] and activity as antibody inhibitors.[61] With respect to electronical properties, diethynyl naphthalene derivatives were previously synthesized which exhibit high ionization potentials for p-channel and n-channel organic field-effect transistors.[62]

In the case of palladium-catalyzed reactions of polyhalogenated substrates the topic of site-selectivity is of significant current interest.[63] The electronic and steric parameters are the factors that mainly control the site-selectivity issue.[64] Palladium-catalyzed reactions of aromatic bis(triflates) have been previously reported. However, the issue of site-selectivity was not addressed.[65] With reference to the site-selectivity in Sonogoshira reactions, Hosokawa *et al.* reported reactions of a bis(triflate) which was prepared from a 1,3-dihydroxybenzene derivative.[66] We observed that Suzuki-Miyaura (S-M) reactions of the bis(triflate) of methyl 2,5-dihydroxybenzoate proceeded with very good site-selectivity in favour of position 5 which is presumably a result of steric effects.[67] I thought that the site-selectivity in the case of naphthoates might be different from that of benzoates, due to electronic reasons. I chose phenyl 1,4-dihydroxy-2-naphthoate as a commercially available and inexpensive starting material as a very good substrate to achieve a better understanding of site-selectivity issue in the naphthalene series. The latter can be regarded as a benzo-annulated analogue of methyl 2,5-dihydroxybenzoate. Transition metal-catalyzed cross coupling reactions of this or related naphthoate derivatives (including the corresponding dihalides) have, to the best of my knowledge, not been reported to date. My research results can be concluded in the way that there is a clear difference in the site-selectivity between benzoate and naphthoate systems.

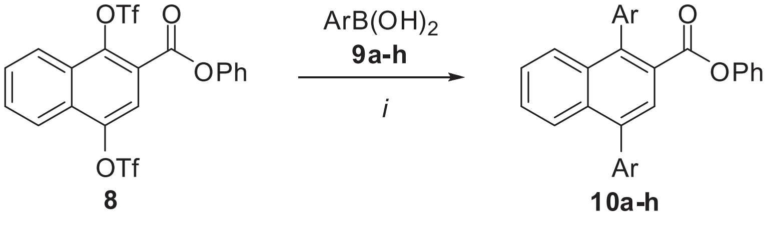
2.3 Results and discussion:

Phenyl 1,4-dihydroxynaphthoate (**7**) was transformed into the novel bis(triflate) **8** in 83% yield (Scheme 5).



Scheme 5: Synthesis of **8**. *Conditions*: *i*: 1) **7** (1.0 equiv), pyridine (4.0 equiv), CH_2Cl_2, -78 °C, 10 min; 2) Tf_2O (2.4 equiv), -78 → 0 °C, 4 h.

The Suzuki-Miyaura (S-M) reaction of **8** with boronic acids **9a-h** (2.4 equiv.) afforded the novel 1,4-diaryl-2-naphthoates **10a-h** in 61-85% yields (Scheme 6, Table 4). The conditions of the reaction were optimized to have the better results with respect to yields and the best combination found was $Pd(PPh_3)_4$ (3 mol-%) as catalyst, 2.4 equiv. boronic acid and 1,4-dioxane (at 110 °C, 8 h) and use of K_3PO_4 as the base. The results were not so good when $Pd(OAc)_2$ in the presence of XPhos[68] or SPhos[68] was used for these reactions to achieve better yields. Later, it was found that the products **10a,b,g** derived from arylboronic acids containing electron-withdrawing substituents gave better yields than **10d,e,h** derived from electron-rich boronic acids.



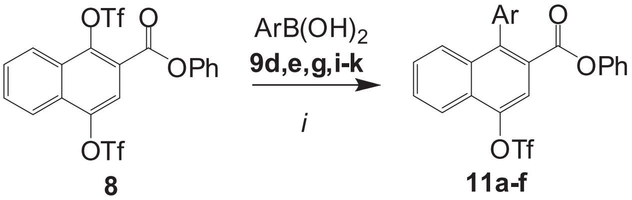
Scheme 6: Synthesis of **10a-h**. *Conditions*: *i*, **8** (1.0 equiv), **9a-h** (2.4 equiv.), K_3PO_4 (3.0 equiv.), $Pd(PPh_3)_4$ (3 mol-%), 1,4-dioxane, 110 °C, 8 h.

Table 4. Synthesis of **10a-h**

9,10	Ar	% (**10**)[a]
a	3-FC_6H_4	85
b	4-$(CF_3)C_6H_4$	80
c	4-MeC_6H_4	76
d	3-$(MeO)C_6H_4$	65
e	2,4-$(MeO)_2C_6H_3$	56
f	C_6H_5	73
g	4-ClC_6H_4	79
h	3,4-$(MeO)_2C_6H_3$	63

[a] Yields of isolated products

In order to get the mono-substituted products of the Suzuki reaction of **8** with boronic acids **9d,e,g,i-k** (1.1 equiv.), I used $Pd(PPh_3)_4$ (3 mol-%) and found that the reaction proceeded with very good site-selectivity at carbon atom C-1 and afforded the 1-aryl-4-(trifluoromethylsulfonyloxy)-2-naphthoates **11a-f** (Scheme 7, Table 5). The products were purified by chromatography. A small amount of the bis-coupled product could be detected by ^1H NMR and GC-MS in the crude material before the purification. Results of these reactions were also very good in consideration of the yield for almost all the boronic acids, except for **11c** which is derived from the sterically hindered 2,6-disubstituted arylboronic acid **9i**. The best yields for these reactions were obtained when the reaction was carried out at 95 °C instead of 110 °C to avoid double coupling.



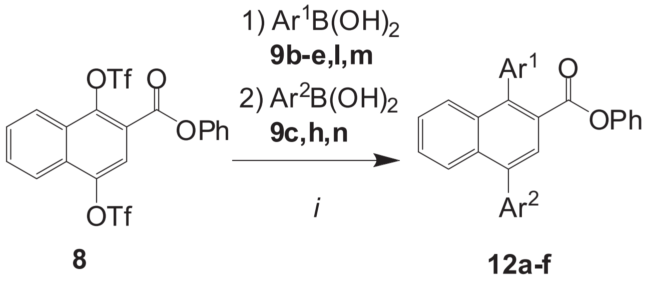
Scheme 7: Synthesis of **11a-f**. *Conditions*: *i*, **8** (1.0 equiv.), **9d,e,g,i-k** (1.1 equiv.), K_3PO_4 (1.5 equiv.), $Pd(PPh_3)_4$ (3 mol-%), 1,4-dioxane, 95 °C, 8 h.

Table 5: Synthesis of **11a-f**

11	**9**	Ar	% (**11**)[a]
a	**k**	2-(EtO)C_6H_4	59
b	**e**	2,4-$(MeO)_2C_6H_3$	66
c	**i**	2,6-$(MeO)_2C_6H_3$	33
d	**g**	4-ClC_6H_4	73
e	**d**	3-(MeO)C_6H_4	69
f	**j**	2-(MeO)C_6H_4	62

[a] Yields of isolated products.

The one-pot reaction of **8** with two different arylboronic acids, which were sequentially added, afforded the unsymmetrical 1,4-diaryl-2-naphthoates **12a-f** in 51-67% yields (Scheme 8, Table 6). During the optimization, it proved to be important, for the first step of the one-pot protocol, to employ only a slight excess of the arylboronic acid (1.1 equiv.) and to carry out the reaction at 95 °C instead of 110 °C.



Scheme 8: Synthesis of **12a-f**. *Conditions:* 1) **8** (1.0 equiv.), **9b-e,l,m** (1.1 equiv.), K_3PO_4 (1.5 equiv.), $Pd(PPh_3)_4$ (3 mol-%), 1,4-dioxane, 95 °C, 7 h. 2) **9c,h,n** (1.3 equiv.), K_3PO_4 (1.5 equiv.), 110 °C, 8 h.

Table 6: Synthesis of **12a-f**

12	**9**	Ar[1]	Ar[2]	% (**12**)[a]
a	**b,h**	4-$(CF_3)C_6H_4$	3,4-$(MeO)_2C_6H_3$	51
b	**d,h**	3-$(MeO)C_6H_4$	3,4-$(MeO)_2C_6H_3$	46
c	**e,c**	2,4-$(MeO)_2C_6H_3$	4-MeC_6H_4	63
d	**c,n**	4-MeC_6H_4	4-$(MeO)C_6H_4$	65
e	**l,n**	3-ClC_6H_4	4-$(MeO)C_6H_4$	61
f	**m,n**	4-$(H_2C{=}CH)C_6H_4$	4-$(MeO)C_6H_4$	67

[a] Yields of isolated products

The structures of **11c** and **12a** were independently confirmed by X-ray crystal structure analyses (Figures 2 and 3).[69]

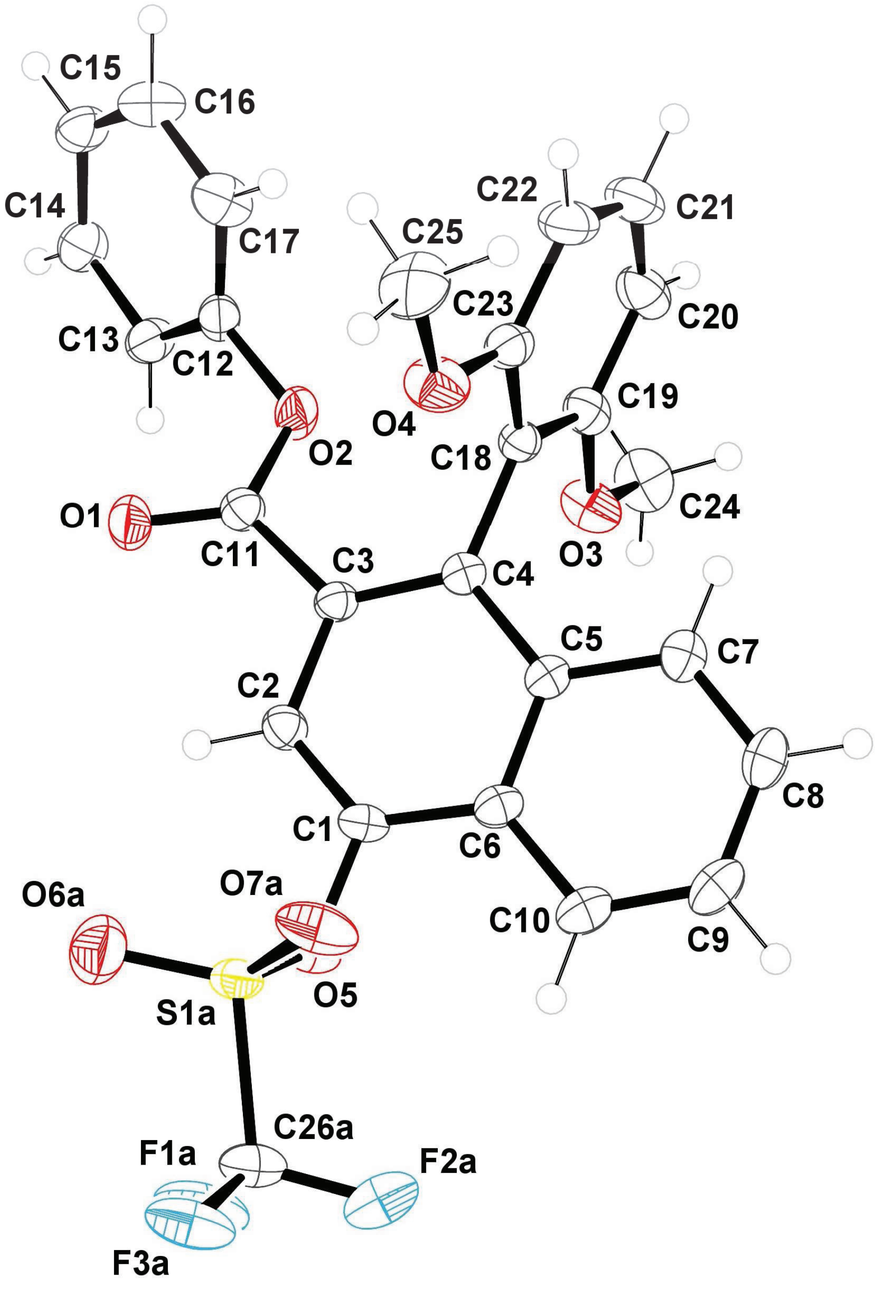


Figure 2: Ortep Plot of **11c**

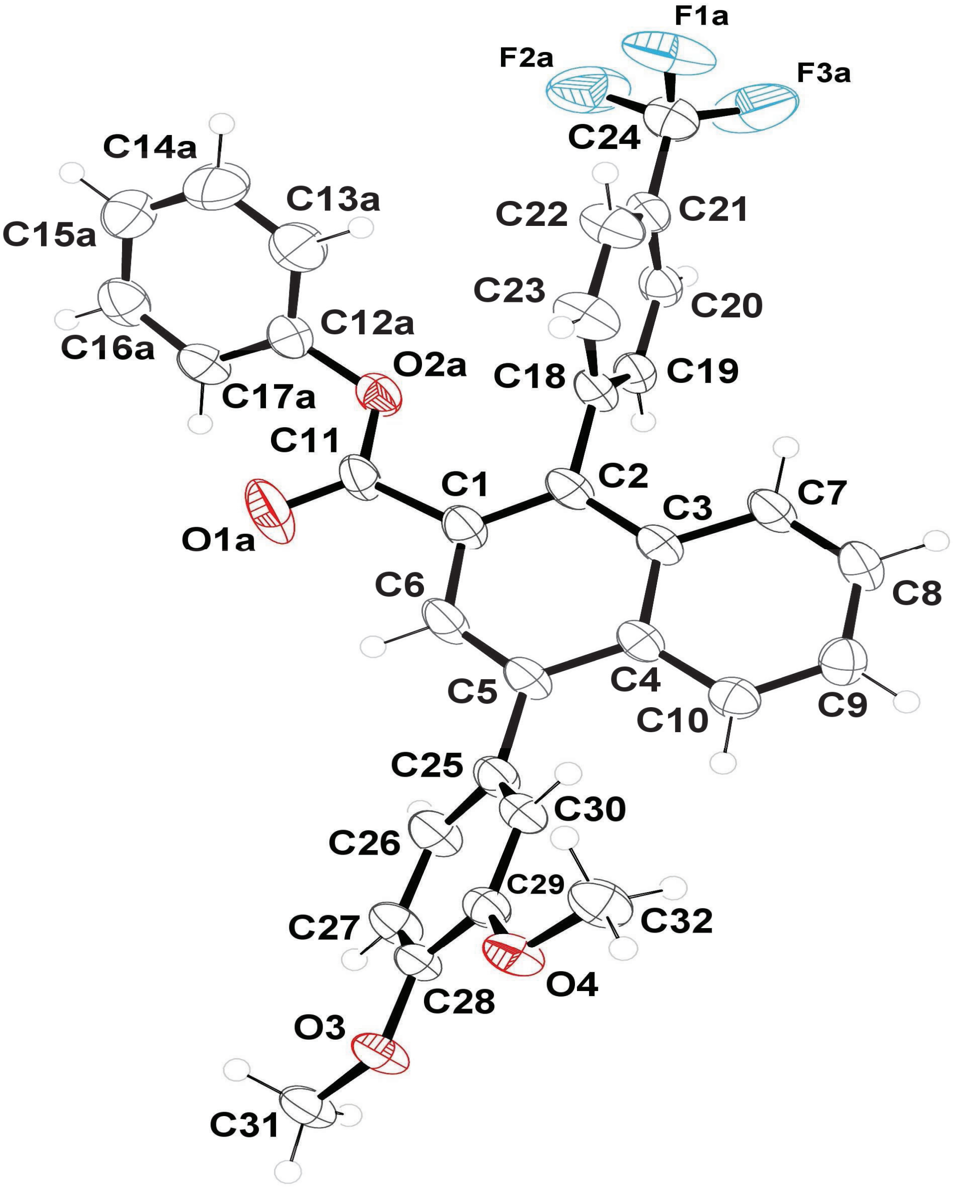
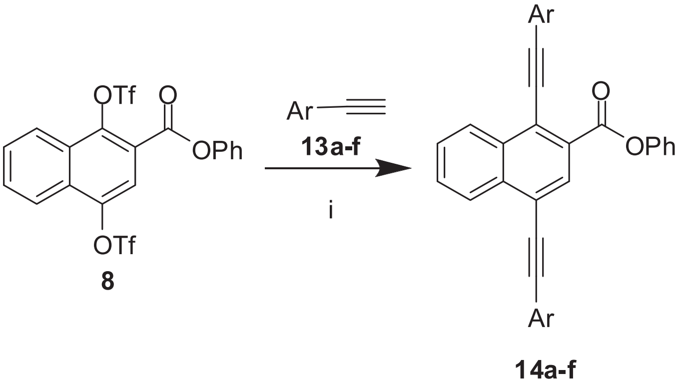


Figure 3: Ortep Plot of **12a**

In a much similar way as adopted for the S-M reaction, the Sonogoshira reaction of **8** with acetylenes **13a-f** (2.4 equiv.) afforded the novel 1,4-bis(alkynyl)-2-naphthoates **14a-f** in 52-77% yields (Scheme 9, Table 7). The best yields were obtained when $Pd(PPh_3)_4$ (10 mol %) and CuI (20 mol %) were used as the catalyst in the presence of tetrabutylammonium iodide (300 mol%), when 2.4 equiv. of the acetylene was employed, and when the reaction was carried out in DMF (80 °C, 4 h) using triethylamine as the base. The difference in yields of the Sonogoshira reaction products can not be generalized with respect to electronic factors. Steric factors may reduce the yield in the case of **14f**.



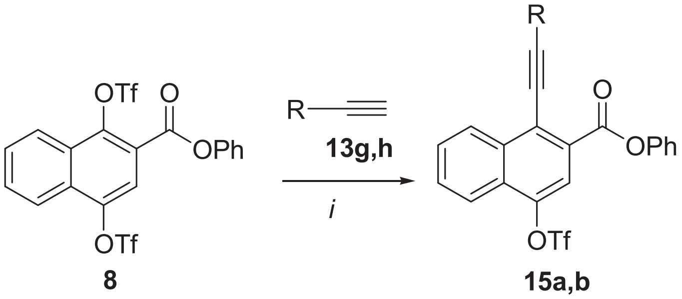
Scheme 9. Synthesis of **14a-f**. *Reagents and conditions:* **8** (1.0 equiv), **13a-f** (2.4 equiv), Dry CuI (20 mol%), $Pd(PPh_3)_4$ (10 mol %), Bu_4NI (300 mol %), Et_3N (2.5 equiv), DMF, 80 °C, 4 h.

Table 7. Synthesis of **14a-f**

13,14	Ar	% (**14**)[a]
a	4-*t*BuC_6H_4	72
b	3-MeC_6H_4	77
c	3-$(MeO)C_6H_4$	68
d	3-FC_6H_4	62
e	4-$(MeO)C_6H_4$	63
f	6-(MeO)-2-Naphthyl	52

[a] Yields of isolated products

The Sonogoshira reactions of **8** with acetylenes **13g** and **13h** (1.1 equiv.), in the presence of $Pd(PPh_3)_4$ (5 mol-%) and CuI(10 mol %), proceeded with good site-selectivity at carbon atom C-1 and afforded the 1-arylethynyl-4-(trifluoromethylsulfonyloxy)-2-naphthoates and 1-alkylethynyl-4-(trifluoromethylsulfonyloxy)-2-naphthoates **15a,b** (Scheme 10, Table 8). This conclusion is based on the comparison of the ^{19}F chemical shifts of the OTf group in the ^{19}F NMR spectra of the products of the Suzuki and the Sonogoshira reactions. The difference of the chemical shifts of the triflate groups is, for all derivatives, approx. 1 ppm and has a systematic character. However, the trend of the shifts is not a strong evidence. Unfortunately, all attempts to unambigiously confirm the regioselectivity by 2D NMR experiments or crystal structure analsis proved to be unsuccessful so far. The products were isolated in pure form after chromatography in good yields 68-72%. In some cases, a small amount of the product derived from double attack could not be completely separated (approx. 10%). The bis-coupled products could be detected by ^{1}H NMR and GC-MS in the crude material before purification by column chromatography. The products were achieved in good yields. It proved to be important to employ only a slight excess of the acetylene (1.1 equiv.) and to carry out the reaction at 60 °C instead of 80 °C to avoid double coupling.



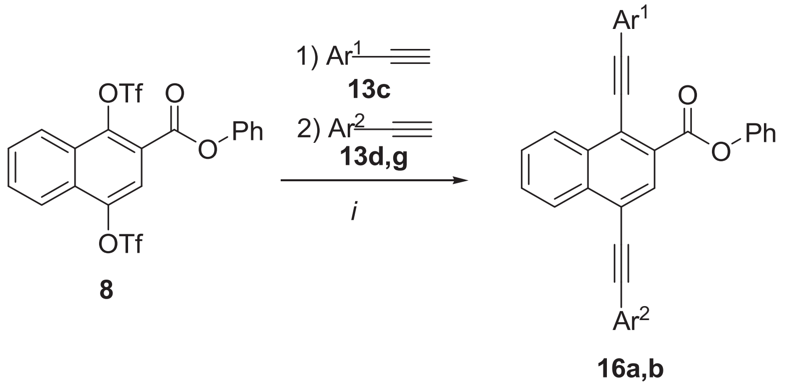
Scheme 10: Synthesis of **15a,b**. *Reagents and conditions:* **8** (1.0 equiv), **13g,h** (1.1 equiv), dry CuI (10%), $Pd(PPh_3)_4$ (5 mol %), Bu_4NI (150 mol %), Et_3N (1.25 equiv), DMF, 60 °C, 4h.

Table 8. Synthesis of **15a,b**

13	15	R	% (**15**) [a]
g	**a**	4-MeC_6H_4	72
h	**b**	Propyl	68

[a] Yields of isolated products

The one-pot reaction of **8** with two different acetylenes, which were sequentially added, afforded the unsymmetrical 1,4-diarylethynyl-2-naphthoates **16a,b** in 54-58% yields (Scheme 11, Table 9). During the optimization it proved to be important for the first step of the one-pot procedure to employ only a slight excess of the acetylene (1.1 equiv.) and to carry out the reaction at 60 °C instead of 80 °C.



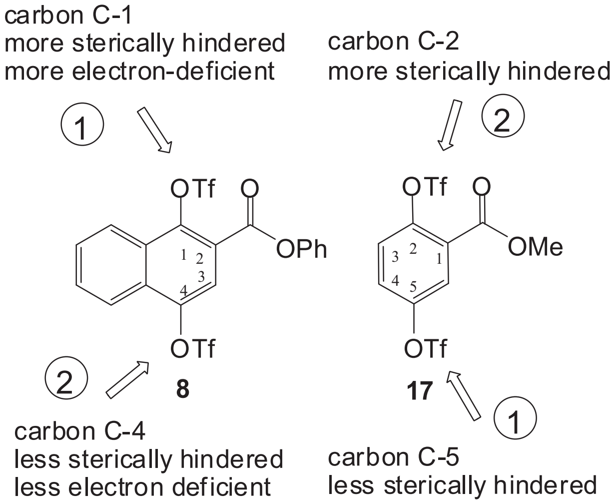
Scheme 11: Synthesis of **16a,b**. *Conditions: i*, 1) **8** (1.0 equiv), **13c** (1.1 equiv), dry CuI (20 mol%), $Pd(PPh_3)_4$ (10 mol %), Bu_4NI (300 mol %), Et_3N (1.25 equiv), DMF, 60 °C, 3 h; 2) **13d,g** (1.3 equiv.), Et_3N (1.25 equiv), 80 °C, 4 h.

Table 9. Synthesis of **16a,b**

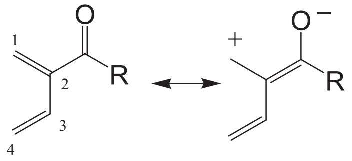
13	16	Ar^1	Ar^2	% (**16**)[a]
c,d	**a**	3-(MeO)C_6H_4	3-FC_6H_4	54
c,g	**b**	3-(MeO)C_6H_4	4-MeC_6H_4	58

[a] Yields of isolated products

The results of the investigations for the regioselective reactions in the case of naphthoate **8** in comparison to the benzoate **17** gave some very interesting results. Previously, it was observed that in the case of benzoate **17** the S-M reaction occurs first at the sterically less hindered carbon atom C-5, whereas in case of naphthoate **8** the first attack occurs at the sterically more hindered position C-1. So the only possible explaination can be a justification by electronic factors (Scheme 12). The oxidative addition of the electron-rich palladium species usually occurs first at the most electron deficient carbon atom.[63] In case of **17**, the more electron deficient carbon atom is carbon C-2 rather than C-5, as it is located at the *ortho* position to the ester group. Similarly in naphthoate **8**, the more electron deficient carbon atom is C-1 rather than C-4, but this deficiency of the electrons in naphthoate is more pronounced than for benzoate **17**. The non-substituted benzene moiety of naphthoate **8** represents a stable 6π aromatic system. In contrast, the aromaticity of the other benzene moiety of **8** is considerably disturbed, because of the presence of the ester and the triflate groups. Due to the annulation of the stable unsubstituted benzene moiety, the aromaticity of the substituted benzene moiety should be more disturbed than the aromaticity of the benzene moiety of **17**. The substituted benzene moiety of **8** might thus be regarded as a cross-conjugated diene system (Scheme 13). Due to the π-acceptor effect of the ester group, the nucleophilic attack occurs at carbon atom C-1 of the diene system (conjugate addition).



Scheme 12. Possible explanation for the site-selective reactions of **8**



Scheme 13. Diene character of **8**

2.4 Conclusion:

In conclusion, I have reported site-selective Suzuki-Miyaura and Sonogoshira reactions of the bis(triflate) of phenyl 1,4-dihydroxynaphthoate. The first attack occurred at the sterically more hindered position C-1.

3. Synthesis of 3,5-diaryl-4-chlorophthalates by [4+2] cycloaddition of 1-ethoxy-2-chloro-1,3-bis(trimethylsilyloxy)-1,3-diene with dimethyl acetylenedicarboxylate and subsequent site-selective Suzuki-Miyaura reactions

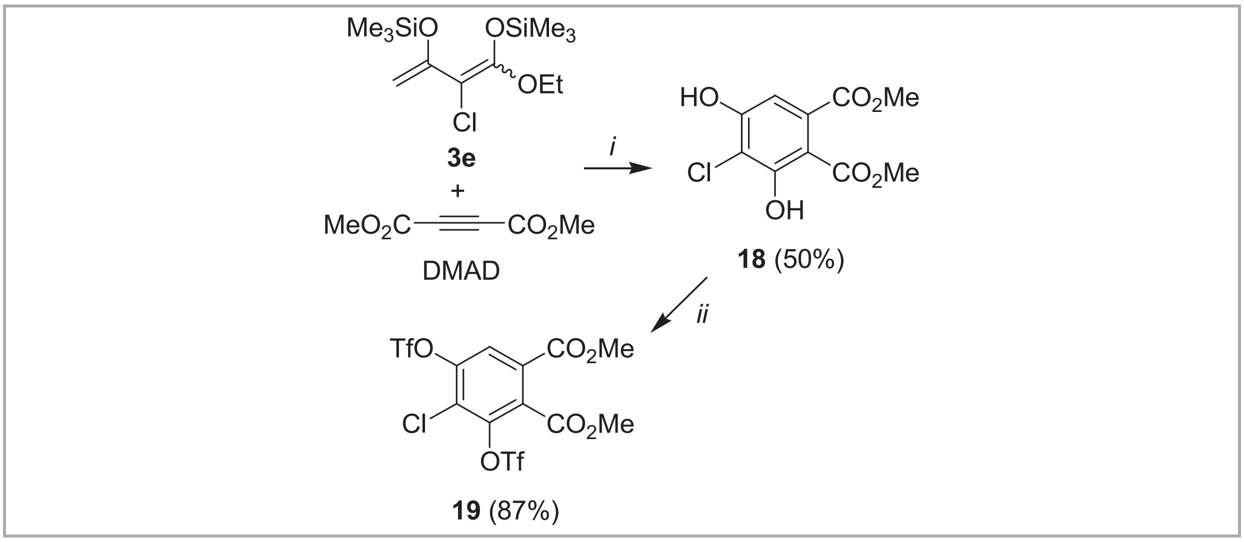
3.1 Introduction:

Aromatic compounds bearing a chloro substituent are found in many natural products and they also exhibit significant pharmacological properties.[70] It is much clear from the literature that the arenes and hetarenes containing a halogen group are pharmacologically much more active than their non-halogenated analogues.[71] Besides this importance with regard to their activity, the chloro group can be effectively reacted in palladium(0)-catalyzed cross coupling reactions using modern catalyst systems.[72] However, the synthesis of chloroarenes is a difficult task which is surrounded by many problems like low regioselectivity or multiple chlorination and other side reactions. An alternative strategy to overcome these problems is the use of proper chlorine-containing building blocks in condensation and cyclization reactions. For example, Manzanares and coworkers reported the synthesis of a 4-chlorophenol by [4+2] cycloaddition of a chlorinated thiophene with dimethyl acetylenedicarboxylate.[73]

1,3-Bis(trimethylsilyloxy)-1,3-butadienes (e. g., Chan's diene)[6,74] are very useful building block for a number of syntheses of different products.[75] Recently, the Langer group took advantage of these building blocks in the synthesis of different arenes and hetarenes in a facile way.[76] Herein, I report, for the first time, the synthesis of dimethyl 4-chloro-3,5-dihydroxyphthalate by [4+2] cycloaddition of 1-ethoxy-2-chloro-1,3-bis(trimethylsilyloxy)-1,3-diene with dimethyl acetylenedicarboxylate (DMAD). The product was then converted to its bis(triflate) which was in turn subjected to Suzuki-Miyaura reactions. These reactions give very good site-selectivities[77] and provide a convenient approach to novel 3,5-diaryl-4-chlorophthalates.

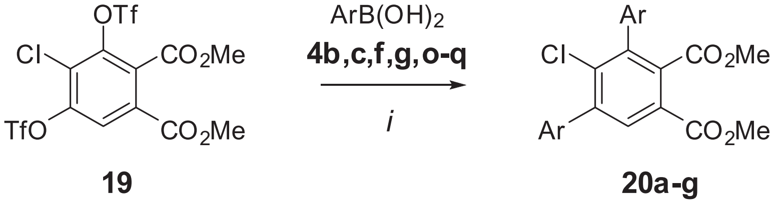
3.2 Results and discussion:

The [4+2] cycloaddition of 1-ethoxy-2-chloro-1,3-bis(trimethylsilyloxy)-1,3-diene (**3e**), readily available from ethyl 2-chloroacetoacetate in two steps, with DMAD resulted in the synthesis of dimethyl 4-chloro-3,5-dihydroxyphthalate (**18**) in 50% yield (Scheme 14). The latter was then treated with triflic anhydride to give its bis(triflate) **19** in high yield.



Scheme 14: Synthesis of **18** and **19**. *Reagents and conditions: i*: 1) **3e** (1.0 equiv.), DMAD (1.5 equiv.), −78 → 20 °C, 20 h; 2) HCl (10%); *ii*, 1) **18** (1.0 equiv), pyridine (4.0 equiv), CH_2Cl_2, -78 °C, 10 min; 2) Tf_2O (2.4 equiv), -78 → 0 °C, 4 h

Using compound **19** in the Suzuki reactions with boronic acids **4b,c,f,g,o-q** (2.4 equiv.), I got the novel 3,5-diaryl-4-chlorophthalates **20a-g** in good yields (Scheme 15, Table 10). During the optimization of the reaction conditions it was found that the use of the catalyst $Pd(PPh_3)_4$ (3 mol-%) and of 2.4 equiv. of the boronic acid give the best results (the reaction was carried out in 1,4-dioxane at 110 °C for 6 h using K_3PO_4 as the base).



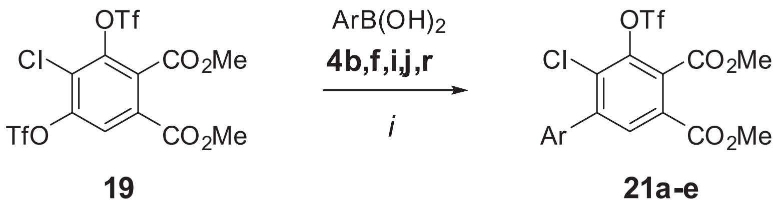
Scheme 15: Synthesis of **20a-g**. *Reagents and conditions: i*, **19** (1.0 equiv), **4b,c,f,g,o-q** (2.4 equiv), K_3PO_4 (3.0 equiv), $Pd(PPh_3)_4$ (3 mol-%), 1,4-dioxane, 110 °C, 6 h.

Table 10 Synthesis of **20a-g**

4,	**20**	Ar	**% (20)**[a]
b	**a**	4-$(CF_3)C_6H_4$	77
f	**b**	C_6H_5	75
g	**c**	4-ClC_6H_4	63
o	**d**	3-$(CF_3)C_6H_4$	49
p	**e**	4-EtC_6H_4	67
c	**f**	4-MeC_6H_4	72
q	**g**	4-FC_6H_4	66

[a] Yields of isolated products

In order to prepare monosubstituted products by Suzuki-Miyaura reactions, **19** was treated with arylboronic acids **4b,f,j,r,i** (1.1 equiv.). As a result, the 5-aryl-4-chloro-3-(trifluoromethylsulfonyloxy)phthalates **21a-e** were formed in good yields and with very good site-selectivity (Scheme 16, Table 11). This selectivity can be explained on the basis of steric factors which look to be very pronounced. I also studied the synthesis of 3,5-diaryl-4-chlorophthalates **22a,b** containing two different aryl groups Ar^1 and Ar^2 which was successfully achieved by direct reaction of bis(triflate) **19** using a one pot procedure (Scheme 17, Table 12). At first, the Suzuki reaction of **19** with arylboronic acid **4p** (1.1 equiv, 90 °C) was done. The subsequent addition of arylboronic acids **4b,a** (1.3 equiv, 110 °C) to the in situ formed mono-coupling product resulted in the synthesis of highly functionalized products **22a,b** in acceptable yields.



19

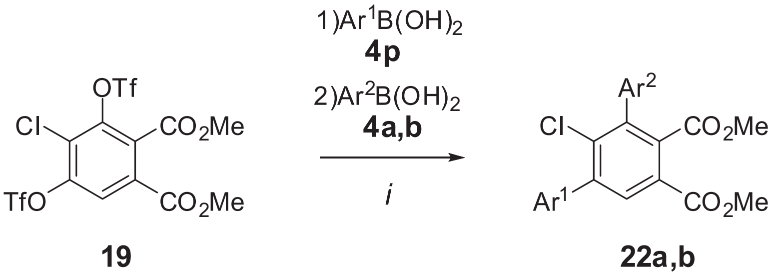
21a-e

Scheme 16: Synthesis of **21a-e**. *Reagents and conditions: i*, **19** (1.0 equiv), **4b,f,i,j,r** (1.1 equiv), K_3PO_4 (1.5 equiv), $Pd(PPh_3)_4$ (3 mol-%), 1,4-dioxane, 90 °C, 8 h.

Table 11. Synthesis of **21a-e**

4	**21**	Ar	% (**21**)[a]
b	**a**	4-$(CF_3)C_6H_4$	63
f	**b**	C_6H_5	65
j	**c**	2-(MeO)C_6H_4	47
r	**d**	3,5-$(Me)_2C_6H_3$	61
i	**e**	2,6-$(MeO)_2C_6H_3$	48

[a] Yields of isolated products



Scheme 17: One-pot synthesis of **22a,b:** *Reagents and conditions: i*, **19** (1.0 equiv), **4p** (1.1 equiv), K_3PO_4 (1.5 equiv), $Pd(PPh_3)_4$ (3 mol-%), 1,4-dioxane, 90 °C, 8 h; *ii*, **4a,b** (1.3 equiv), K_3PO_4 (1.5 equiv), 110 °C, 6 h.

Table 12. Synthesis of **22a-b**

4	**22**	Ar^1	Ar^2	% (**22**)[a]
p, b	**a**	4-EtC_6H_4	4-$(CF_3)C_6H_4$	57
p, a	**b**	4-EtC_6H_4	3-FC_6H_4	53

[a] Yields of isolated products

The structure of product **21b** was established by 2D NMR experiments (HMBC, NOESY) (Figure 4). The structure of **22a** was independently confirmed by X-ray crystal structure analysis (Figure 5).[78]

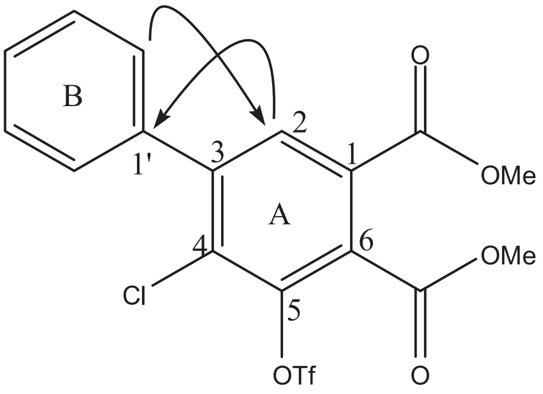


Figure 4: Structure elucidation of **21b**

The structure of this compound (**21b**) was confirmed by 2D NMR. The signals of the carbons found in the ^{13}C NMR spectrum were exactly assigned with the help of HMQC experiments to δ 131.9 (C-2), 136.8 (C-3) and 131.6 (C-1'). In the HMBC spectrum, the aromatic proton attached to C-2 showed a coupling with the quaternary carbon of ring B. In addition, the aromatic protons located at the *ortho* position of ring B showed an interaction with carbon C-2. In the NOESY spectrum, an interaction was observed between the aromatic proton of ring A with the *ortho* protons of ring B.

3.3 Conclusion:

In conclusion, I reported a convenient approach to dimethyl 4-chloro-3,5-dihydroxyphthalate by [4+2] cycloaddition of 1-ethoxy-2-chloro-1,3-bis(trimethylsilyloxy)-1,3-diene with dimethyl acetylenedicarboxylate (DMAD). Suzuki-Miyaura reactions of the bis(triflate) of the product proceed with very good site-selectivity and provide a convenient approach to 3,5-diaryl-4-chlorophthalates.

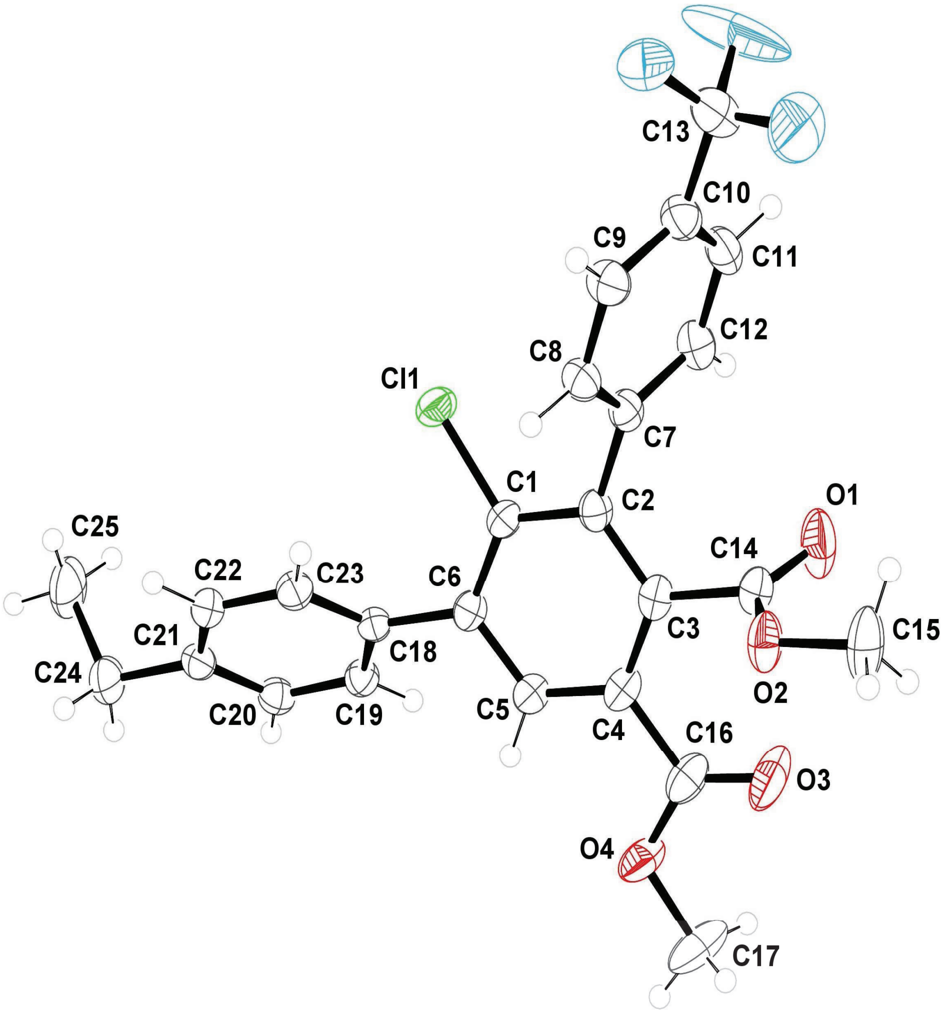


Figure 5: Ortep Plot of **22a**

4. Synthesis of functionalized arylpyridines and arylpyrimidines based on a Diels-Alder approach

4.1 Introduction:

Pyridine containing biaryl structures are of considerable importance specifically with respect to their use in pharmaceutical industry and their utility as ligands in metal catalysis.[79] These molecules have shown activity in a wide range of therapeutic classes like antifungal, anti-inflammatory, antirheumatic, antitumor, and antihypertensive agents.[80] Heterocyclic biaryls are also very potent structures and have been shown to be useful as antibacterial agents by inhibiting Gram-positive and Gram-negative bacteria[81] and as anti-inflammatory agents. 4-Phenylpyridines have also been reported as a novel class of selective glucagon antagonists.[82] In particular, 4-aryl-1,4-dihydropyridine compounds are already in use for the treatment of a number of cardiovascular disorders, such as hypertension, cardiac arrhythmias or angina.[83,84] (Pyrid-2-yl)arenes are present in natural 4-azafluorenones (e. g. kinabaline, darienine, and onychine) which exhibit a strong antimicrobial activity.[85]

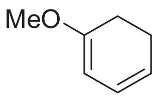
Because of the significant importance of biaryls possessing *N*-heterocyclic moieties in the field of natural products, molecular recognition and asymmetric reactions,[86] new strategies for their assembly are always required to overcome existing limitations. For the synthesis of biaryl linkages, a number of methods have been developed, particularly involving the use of palladium-mediated strategies, such as the Kharasch, Negishi, Stille, and Suzuki reactions.[87] Homo-coupling reactions of heterocyclic aromatic bromides leading to symmetric molecules, using $Pd(OAc)_2$ and indium species, have also been reported.[88] The synthesis of arylpyridines has been achieved by direct cross-coupling of aryl halides and boronic acids. This strategy has been effectively applied to the use of both pyridyl halides as well as pyridine boronic acids as the coupling partners.[89] Recently, Langer *et al*. reported formal [3+3] cyclizations of 1,3-bis(silyl enol ethers) with 3-pyridyl-3-silyloxy-2-en-1-ones which offer a convenient and regioselective approach to functionalized and sterically encumbered 6-(pyridyl)salicylates.[90]

In the recent few years, Rich G. Carter and coworkers have developed very efficient Diels-Alder reactions for the synthesis of a variety of functionalized biaryls using *ortho*-

nitrophenyl-acetylenes.[91] The nitro group plays a crucial role in these reactions (with regard to the excellent regioselectivity, mild reaction conditions and high rate of the reactions). We thought that it might be very useful to extend this strategy to the use of electron-deficient heterocyclic aromatic systems to explore the potential of this methodology. In my thesis, I studied the [4+2] cycloaddition of pyridyl- and pyrimidyl-substituted acetylenes with various electron-rich dienes to prepare functionalized arylpyridines and arylpyrimidines. These reactions represent, similar to the reactions of Carter, Diels-Alder reactions with normal electron demand.

4.2 Results and Discussion:

Similar to the work of Carter *et al.*, the three dienes **23-25** were chosen for my study. Out of these three dienes, diene **23** and **24** were commercially available while diene **25** was synthesized by reaction of the corresponding cyclohexenone with LDA and TMSCl at -78 °C.[91a]



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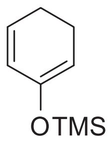

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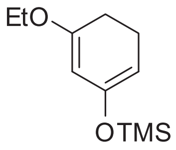
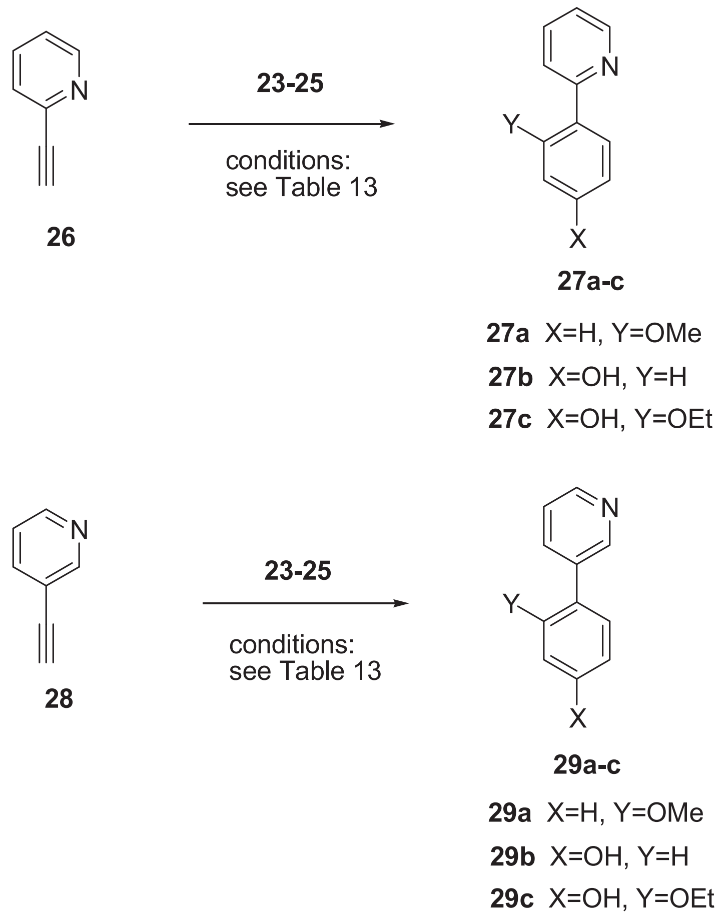


25

The reactions of dienes **23-25** with the commercially available acetylenes **26** and **28** yielded the products **27a-c** and **29a-c** in moderate to good yields 42-63%, respectively (Scheme 18, Table 13). The reactions were carried out at 140 °C. This temperature was found to be the most effective to achieve high yields. The higher yield in the case of 2-pyridyl acetylene compared to 3-pyridylacetylene can be attributed to the stronger electronic-withdrawing effect of the 2-pyridyl moiety. The structure of **27c** was independently confirmed by X-ray crystal structure analysis (Figure 6).



Scheme 18: Diels-Alder reactions of acetylenes **26** and **28**

Table 13: Synthesis of **27a-c** and **29a-c**

Diene	Acetylene	Conditions	Product	Yield (%) [a]
23	**26**	140 °C, 4hr	**27a**	63
24	**26**	140 °C, 4hr, K_2CO_3, MeOH, 15min	**27b**	57
25	**26**	140 °C, 4hr, K_2CO_3, MeOH, 15min	**27c**	55
23	**28**	140 °C, 16hr	**29a**	52
24	**28**	140 °C, 6hr, K_2CO_3, MeOH, 15min	**29b**	44
25	**28**	140 °C, 6hr, K_2CO_3, MeOH, 15min	**29c**	42

[a] Yields of isolated products

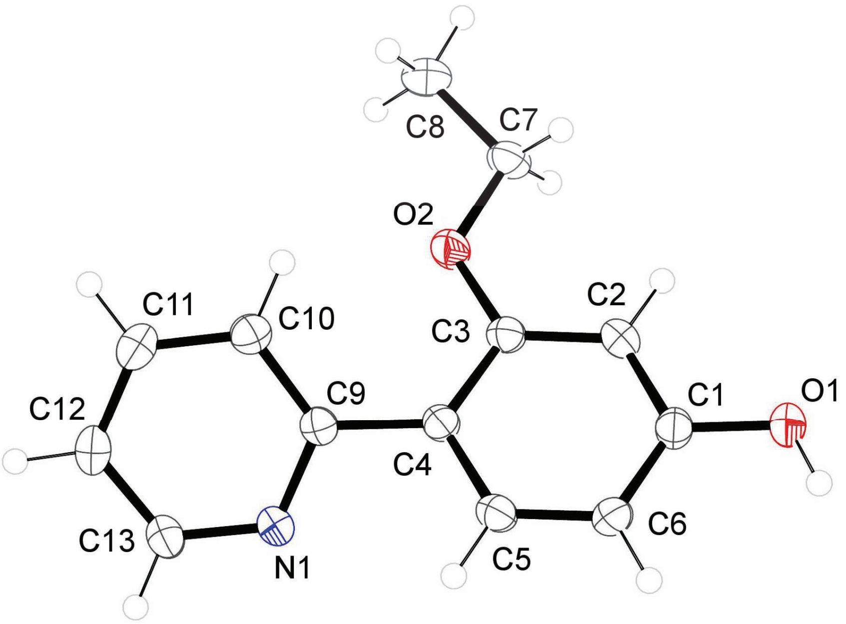
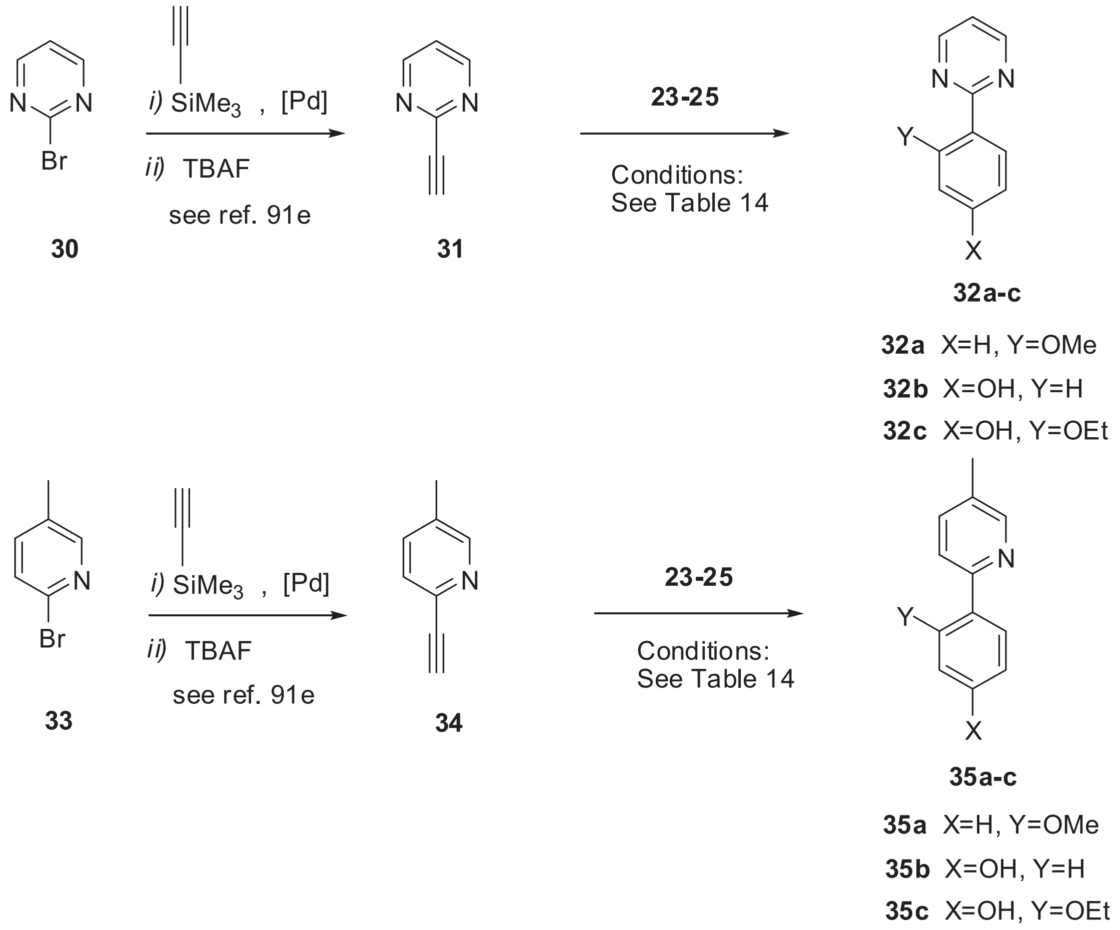


Figure 6: Ortep Plot of **27c**

In order to study the efficiency of the presence of 2-pyridyl acetylene and also to study the effect of the presence of substituents present in the 2-pyridyl ring, I thought it would be worthy to synthesize the acetylenes **31** and **34** from commercially available starting materials following literature procedures.[91e] The synthesis of the acetylenes **31** and **34** involved the palladium catalyzed reaction of the respective pyridyl and pyrimidyl bromides with TMS-acetylene and subsequent removal of TMS using TBAF. The reactions of acetylenes **31** and **34** with dienes **23-25** afforded the products **32a-c** and **35a-c** in good yields (Scheme 19, Table 14). As supposed earlier, the strong electron-withdrawing effect of the neighbouring nitrogen atoms in acetylene **31** proved to be important to afford the product in very good yields (62-69%). However, it was noted that the presence of a weak electron-donating group in the pyridyl ring can considerably decreased the yield as was evident from the use of acetylene **34** having a methyl group (the yields dropped to 43-55%).



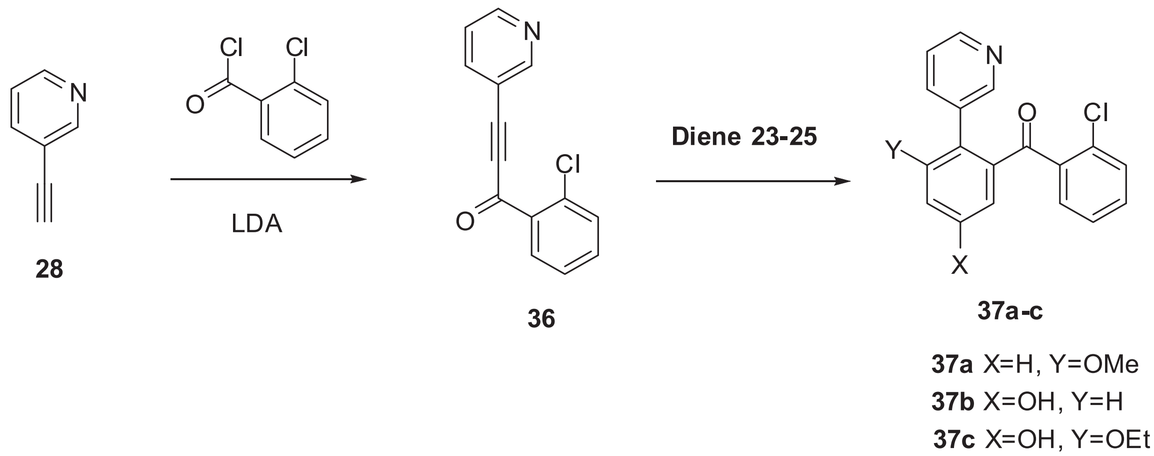
Scheme 19: Diels-Alder reactions of acetylenes **31** and **34**

Table 14: Synthesis of **32a-c** and **35a-c**

Diene	Acetylene	Conditions	Product	Yield (%) [a]
23	**31**	140 °C, 2hr	**32a**	69
24	**31**	140 °C, 3hr, K_2CO_3, MeOH, 15min	**32b**	62
25	**31**	140 °C, 3hr, K_2CO_3, MeOH, 15min	**32c**	62
23	**34**	140 °C, 4hr	**35a**	55
24	**34**	140 °C, 6hr, K_2CO_3, MeOH, 15min	**35b**	43
25	**34**	140 °C, 6hr, K_2CO_3, MeOH, 15min	**35c**	48

[a]Yields of isolated products

To study the effect of introducing an electron-withdrawing effect on the free position of the alkyne and to broaden the scope of this strategy, I synthesized acetylene **36.** This synthesis involves the treatment of acetylene **28** with LDA followed by the addition of the acid chloride.[91b] The reaction of this acetylene **36** with the dienes **23-25** resulted in the synthesis of the highly functionalized products **37a-c** in 55-61% yields (Scheme 20, Table 15). It should be noted that, by increasing the electron withdrawing effect on the second terminus of the acetylene **28**, I was not only able to introduce an additional substituent but also to increase the yield of the products. In fact, the yields of products **37a-c** were higher than those of **29a-c** (all derived from **28**).



Scheme 20: Diels-Alder reactions of acetylene **36**

Table 15: Synthesis of **37a-c**

Diene	Acetylene	Conditions	Product	Yield (%) [a]
23	**36**	140 °C, 2hr	**37a**	61
24	**36**	140 °C, 3hr, K_2CO_3, MeOH, 15min	**37b**	51
25	**36**	140 °C, 3hr, K_2CO_3, MeOH, 15min	**37c**	55

[a]Yields of isolated products

4.3 Conclusion:

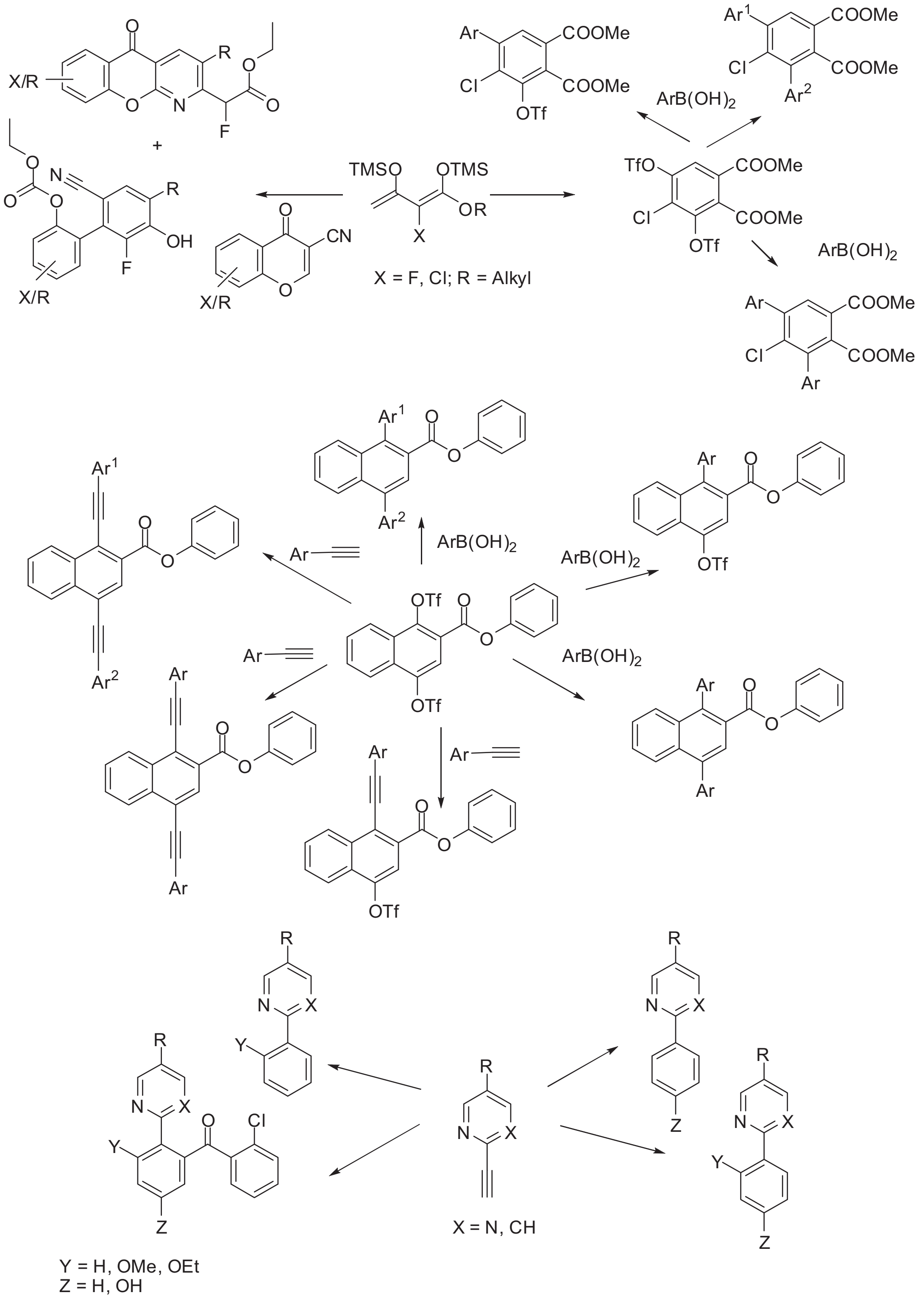
In conclusion, I reported the Diels-Alder reaction of pyridyl-substituted acetylenes with electron-rich dienes. Especially 2-pyridyl-acetylene and 2-pyrimidyl-acetylene give very good yields for the synthesis of aryl-pyridines and -pyrimidines. The degree of substitution and complexitiy can be increased by the introduction of an electron withdrawing carbonyl group at the second terminus of the acetylene moiety.

5. Abstract

Regioselective cyclocondensation reactions of 1,3-bis(silyl enol ethers) with different electrophiles provide a facile approach for the synthesis of various products from simple starting materials. Fluorinated biaryls and azaxanthones are prepared based on domino reactions of substituted 2-fluoro-1,3-bis(silyloxy)-1,3-butadienes with different cyanochromones. The mechanism and product distribution depends on the substitution pattern of the diene. The Diels-Alder reaction of 1-ethoxy-2-chloro-1,3-bis(trimethylsilyloxy)-1,3-butadiene with dimethylacetylene dicarboxylate (DMAD) yielded 4-chloro-3,5-dihydroxyphthalate which was converted to its bis(triflate). The Suzuki-Miyaura reaction of this substrate with various arylboronic acids proceeded with very good site-selectivity. The selectivity is controlled by steric parameters. Suzuki-Miyaura and Sonogoshira reactions of the bis(triflate) of phenyl 1,4-dihydroxy-2-naphthoate also proceeded with very good site-selectivity. The selectivity is controlled by electronic rather than steric parameters as the first attack occurs at the sterically more hindered position. The Diels-Alder reaction of pyridyl- and pyrimidyl-substituted acetylenes with electron-rich dienes was studied. These reactions provide a convenient approach to various functionalized arylpyridines and arylpyrimidines.

Die regioselektive Cyclokondensation von 1,3-Bis(silylenolethern) mit verschiedenen Elektrophilen ermöglicht einen einfachen Zugang fzu vielfältigen Produkten ausgehend von einfachen Startmaterialien. Fluorinierte Biaryle und Azaxanthone wurden durch Dominoreaktionen von substituierten 2-Fluoro-1,3-bis(silyloxy)-1,3-butadienen mit Cyanochromonen. Der Mechanismus und die Produktverteilung hängt vom Substitutionsmuster der Diene ab. Die Diels-Alder Reaktion von 1-Ethoxy-2-chloro-1,3-bis(trimethylsilyloxy)-1,3-butadienen mit Dimethylacetylendicarboxylat (DMAD) lieferte 4-Chloro-3,5-dihydroxyphthalate, die in die entsprechenden Bis(triflate) überführt wurden. Die Suzuki-Miyaura-Reaktionen dieses Substrates mit verschiedenen Arylboronsäuren verliefen mit sehr guter Regioselektivität, die durch sterische Parameter kontrolliert wird. Suzuki-Miyaura und Sonogoshira Reaktionen des Bis(triflates) von Phenyl 1,4-dihydroxy-2-naphthoat verliefen ebenfalls mit sehr guter Regioselektivität, die allerdings hier durch elektronische und nicht sterische Parameter kontrolliert wird. Der erste Angriff findet an dem sterisch stärker gehinderten Zentrum statt. Die Diels-Alder Reaktion von Pyridyl- und

Pyrimidyl-substituierten Alkinen mit elektronenreichen Dienen ermöglicht einen einfachen Zugang zu verschiedenen Arylpyridinen und Arylpyrimidinen.



Scheme 21: Content of the present thesis

6. Experimental Section:

6.1 General: Equipment, chemicals and work technique

^{1}H NMR Spectroscopy:

Bruker: AM 250, Bruker ARX 300, Bruker ARX 500; δ = 0.00 ppm for Tetramethylsilane; δ = 2.04 ppm for Acetone-d_6; δ = 7.26 ppm for ($CDCl_3$); 2.50 ppm for DMSO-d_6; Characterization of the signal fragmentations: s = singlet, d = doublet, dd = double of doublet, ddd = doublet of a double doublet, t = triplet, q = quartet, quint = quintet; sext = Sextet, sept = Septet, m = multiplet, br = broadly. Spectra were evaluated according to first order rule. All coupling constants are indicated as (*J*).

^{13}C NMR Spectroscopy:

Bruker: AM 250, (62.9 MHz); Bruker: ARX 300, (75 MHz), Bruker: ARX 500, (125 MHz) Ref: 29.84 ± 0.01 ppm and 206.26 ± 0.13 ppm for $(CD_3)_2CO$. δ = 128.00 ppm for benzene-d_6; δ = 77.00 ppm for $CDCl_3$. The multiplicity of the carbon atoms was determined by the DEPT 135 and APT technique (APT = Attached Proton Test) and quoted as CH_3, CH_2, CH and C for primary, secondary, tertiary and quaternary carbon atoms. Characterization of the signal fragmentations: quart = quartet the multiplicity of the signals was determined by the DEPT recording technology and/or the APT recording technology.

Mass Spectroscopy:

AMD MS40, AMD 402 (AMD Intectra), Varian MAT CH 7, MAT 731.

High Resolution mass spectroscopy:

Finnigan MAT 95 or Varian MAT 311; Bruker FT
CIR, AMD 402 (AMD Intectra).

Infrared spectroscopy (IR):

Bruker IFS 66 (FT IR), Nicolet 205 FT IR; Nicolet Protege 460, Nicolet 360 Smart Orbit (ATR); KBr ,KAP, Nujol, and ATR; Abbreviations for signal allocations: w = weak, m = medium, s = strong, br = broad.

Elementary analysis:

LECO CHNS-932, Thermoquest Flash EA 1112.

X-ray crystal structure analysis:

Bruker X8Apex Diffractometer with CCD-Kamera (Mo-K_a und Graphit Monochromator, $\lambda = 0.71073$ Å).

Melting points:

Micro heating table HMK 67/1825 Kuestner (Büchi apparatus); Melting
points are uncorrected.

Column chromatography:

Chromatography was performed over Merck silica gel 60 (0,063 -0,200 mm, 70 - 230 mesh) as normal and/or over mesh silica gel 60 (0,040 - 0,063 mm, 200 -400 mesh) as Flash Chromatography. All solvent were distilled before use.

TLC:

Merck DC finished foils silica gel 60 F_{254} on aluminum foil and Macherey finished
foils Alugram® Sil G/UV_{254}. Detection under UV light with 254 nm and/or 366 nm without dipping reagent, as well as with anisaldehyde sulfuric acid reagent (1 mL anisaldehyde consisting in 100 mL stock solution of 85% methanol, 14% acetic acid and 1% sulfuric acid).

Chemicals and work technique:

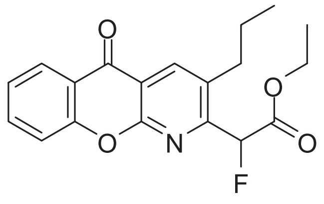
All solvents for using were distilled by standard methods. All reactions were carried out under an inert atmosphere, oxygen and humidity exclusion. All of the chemicals are standard, commercially available from Merck®, Aldrich®, Arcos® and others. The order of the characterized connections effected numerically, but does not correspond to the order in the main part of dissertation.

6.2 Procedures and Spectroscopic Data:

General procedure for the synthesis of azaxanthones 5 and biaryls 6:

To neat 3-cyanochromone **4** (1.0 equiv.) was added Me_3SiOTf (1.3 equiv.) and CH_2Cl_2 (1 mL) at 20 °C. After stirring for 1 h, CH_2Cl_2 (9 mL) and 1,3-bis(trimethylsilyloxy)-1,3-butadiene **3** (1.3 equiv.) were added at 0 °C. The mixture was stirred for 12 h at 20 °C and subsequently poured into hydrochloric acid (10%). The organic and the aqueous layer were separated and the latter was extracted with CH_2Cl_2 (3 x 100 mL). The combined organic layers were washed with water, dried (Na_2SO_4), filtered and the filtrate was concentrated *in vacuo*. The residue was dissolved in ethanol (10 mL), NEt_3 (2.0 equiv.) was added and the solution was stirred for 12 h at 20 °C. To the solution were subsequently added an aqueous solution of hydrochloric acid (1 M) and ether (50 mL). The organic and the aqueous layer were separated and the latter was extracted with ether (3 x 100 mL). The combined organic layers were washed with water, dried (Na_2SO_4), filtered and the filtrate was concentrated *in vacuo*. The residue was purified by column chromatography (silica gel, EtOAc/hexane).

Ethyl 2-fluoro-2-(5-oxo-3-propyl-5*H*-chromeno[2,3-*b*]pyridine-2-yl)acetate (5b):

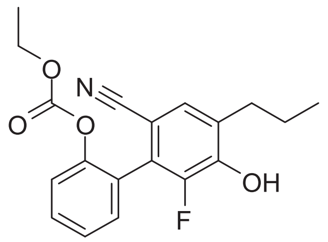


Chemical Formula: $C_{19}H_{18}FNO_4$
Exact Mass: 343.12

Starting with 3-cyanochromone **4a** (171 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3b** (435mg, 1.30 mmol), CH_2Cl_2 (10.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **5b** was isolated as a light yellow solid (58 mg, 17%), m.p 88-90°C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.97 (t, J = 7.3 Hz, 3H, CH_3), 1.23 (t, J = 6.9 Hz, 3H, CH_3), 1.60-1.77 (m, 2H, CH_2) , 2.70-2.86 (m, 2H, CH_2), 4.19-4.35 (m, 2H, OCH_2), 6.07 (d, J_{FH} = 47.7 Hz, CH), 7.36 (t, J = 7.5 Hz, 1H, ArH), 7.53 (d, J = 8.1 Hz, 1H, ArH), 7.72 (dt, J = 7.8, 1.7 Hz, 1H, ArH), 8.24 (d, J = 8.1 Hz, 1H, ArH), 8.53 (s, 1H, ArH); ^{13}C NMR (62.90 MHz, $CDCl_3$): δ = 13.2 (CH_3), 14.1 (CH_3), 24.1 (CH_2), 32.5 (CH_2), 62.3 (OCH_2), 87.9 (d, J_{FC} = 188 Hz, FC), 117.0 (d, J_{FC} = 1.8 Hz, C), 118.5 (CH), 121.5 (C), 124.7, 126.7 (2CH), 135.1 (C), 135.8, 138.9 (2CH), 155.6 (d, J_{FC} = 18.8 Hz, C), 155.8 (C), 157.8 (C), 167.0 (d, J_{FC} = 25.6 Hz, C=O), 177.3 (C=O); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -182.15 (CF); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3359 (w), 3054 (w), 3071 (w), 2964 (w), 2920 (w), 2850 (w), 1762 (s), 1663 (s), 1601 (s), 1562 (w), 1469 (m), 1438 (m), 1423 (s), 1374 (m), 1312 (m), 1201 (m), 1099 (m), 1054 (s), 1014 (m), 754 (s), 665 (m), 595 (w); MS (GC, 70 eV): *m/z*

(%): 345 (M^++2, 2), 344 (M^++1, 15), 343 (M^+, 75), 328 (100), 315 (15), 294 (7), 270 (17), 254 (39), 210 (7), 139 (3), 121 (3), 76 (4), 51 (1); HRMS (EI) calcd for $C_{19}H_{18}FNO_4$ [M^+]: 343.12144, found 343.121662.

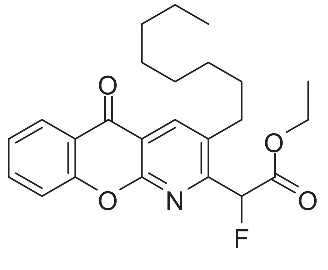
6'-Cyano – 2'- fluoro – 3'- hydroxyl – 4'- propylbiphenyl – 2 – yl ethyl carbonate (6b) :



Chemical Formula: $C_{19}H_{18}FNO_4$
Exact Mass: 343.12

Starting with 3-cyanochromone **4a** (171 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3b** (435mg, 1.30 mmol), CH_2Cl_2 (10.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **6b** was isolated as a light yellow crystals (244 mg, 71%), m.p 110-112°C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.90 (t, J = 7.5 Hz, 3H, CH_3), 1.13 (t, J = 7.0 Hz, 3H, CH_3), 1.52-1.64 (m, 2H, CH_2) , 2.57 (dt, J_{HH} = 7.5 Hz, J_{FH} = 1.5 Hz, 2H, CH_2), 4.08 (q, J = 7.1 Hz, 2H, OCH_2), 6.19 (brs, 1H, OH), 7.25 (s, 1H, ArH), 7.27-7.35 (m, 3H, ArH), 7.41 (dt, J = 7.2, 2.1 Hz, 1H, ArH); ^{13}C NMR (62.90 MHz, $CDCl_3$): δ = 13.8 (CH_3), 13.9 (CH_3), 22.8 (CH_2), 31.4 (d, J_{FC} = 2.3 Hz, CH_2), 65.0 (OCH_2), 104.2 (d, J_{FC} = 4.6 Hz, C), 117.4 (d, J_{FC} = 3.7 Hz, CN), 122.3 (CH), 124.0 (C), 126.0 (d, J_{FC} = 18 Hz, C), 126.3 (CH), 130.3 (d, J_{FC} = 3.0, CH), 130.7 (CH), 131.4 (CH), 132.2 (d, J_{FC} = 2.7 Hz, C), 146.1 (d, J_{FC} = 15.8 Hz, C-OH), 147.9 (d, J_{FC} = 260 Hz, C), 148.6 (C), 152.7 (C=O);); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -138.29 (ArF); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3305 (b), 2962 (w), 2932 (w), 2872 (w), 2225 (w), 1762 (m), 1617 (m), 1480 (s), 1433 (m), 1369 (m), 1242 (s), 1203 (s), 1152 (m), 1094 (m), 996 (m), 900 (w), 767 (m), 665 (w), 579 (w); MS (GC, 70 eV): *m/z* (%): 343 (M^+, 2), 326 (1), 299 (5), 284 (35), 271 (35), 254 (7), 243 (26), 242 (100), 228 (7), 207 (6), 177 (3), 158 (3), 139 (3), 94 (1), 44 (7), 32 (32) ; HRMS (EI) calcd for $C_{19}H_{18}FNO_4$ [M^+]: 343.12144, found 343.122296.

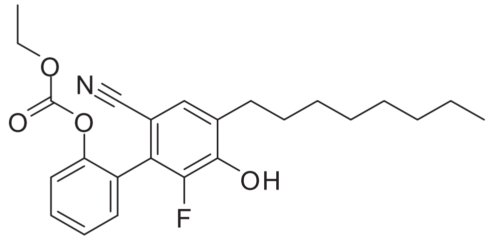
Ethyl 2-fluoro-2-(3-octyl- 5-oxo-5H-chromeno[2,3-b]pyridin-2-yl)acetate (5c):



Chemical Formula: $C_{24}H_{28}FNO_4$
Exact Mass: 413.20

Starting with 3-cyanochromone **4a** (171 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3c** (526mg, 1.30 mmol), CH_2Cl_2 (10.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **5c** was isolated as a light yellow solid (83 mg, 20%), m.p 65-67°C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.80 (t, J = 6.7 Hz, 3H, CH_3), 1.17-1.39 (m, 13H), 1.57-1.69 (m, 2H, CH_2), 2.74-2.84 (m, 2H, CH_2), 4.19-4.35 (m, 2H, OCH_2), 6.06 (d, J_{FH} = 47.7 Hz, CH), 7.35 (t, J = 7.4 Hz, 1H, ArH), 7.52 (d, J = 8.3 Hz, 1H, ArH), 7.70 (dt, J = 7.7, 1.6 Hz, 1H, ArH), 8.22 (dd, J = 8.0, 1.2 Hz, 1H, ArH), 8.52 (s, 1H, ArH); ^{13}C NMR (62.90 MHz, $CDCl_3$): δ = 14.0 (CH_3), 14.1 (CH_3), 22.6, 29.1, 29.3, 29.4, (4CH_2), 30.6 (d, J_{FC} = 1.4 Hz, CH_2), 30.9, 31.8, (2CH_2), 62.2 (OCH_2), 87.9 (d, J_{FC} = 188 Hz, FC), 117.0 (d, J_{FC} = 1.8 Hz, C), 118.5 (CH), 121.5 (C), 124.7 (CH), 126.7 (CH), 135.3 (C), 135.8 (CH), 138.9 (CH), 155.5 (d, J_{FC} = 18.6 Hz, C), 155.8 (C), 157.7 (C), 167.0 (d, J_{FC} = 25.6 Hz, C=O), 177.3 (C=O); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -182.14 (FC); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3359 (w), 3052 (w), 2954 (w), 2920 (m), 2851 (w), 1762 (s), 1663 (s), 1602 (s), 1558 (w), 1469 (s), 1438 (m), 1425 (s), 1369 (m), 1316 (m), 1270 (m), 1228 (m), 1152 (m), 1063 (m), 1029 (m), 960 (m), 850 (w), 760 (s), 698 (m), 582 (w); MS (GC, 70 eV): *m/z* (%): 414 (M^++1, 1), 413 (M^+,3), 398 (1), 384 (3), 340 (3), 328 (28), 309 (23), 308 (100), 254 (14), 242 (20), 210 (4), 29 (4); HRMS (EI) calcd for $C_{24}H_{28}FNO_4$ [M^+]: 413.19969, found 413.200185.

6'-Cyano-2'-fluoro-3'-hydroxy-4'-octylbiphenyl-2-yl ethyl carbonate (6c):

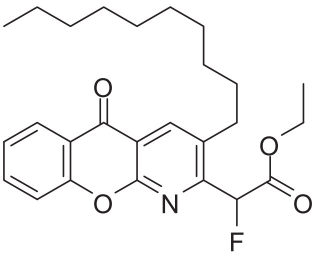


Chemical Formula: $C_{24}H_{28}FNO_4$
Exact Mass: 413.20

Starting with 3-cyanochromone **4a** (171 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3c** (526mg, 1.30 mmol), CH_2Cl_2 (10.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **6c** was isolated as a dark yellow viscous gel (260 mg, 63%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.81 (t, J = 7.2 Hz, 3H, CH_3), 1.1-1.3 (m, 13H), 1.5 (t, J = 7.0 Hz, 2H, CH_2), 2.58 (t, J = 7.5 Hz, 2H, CH_2), 4.08 (q, J = 7.1 Hz, 2H, OCH_2), 6.47 (brs, 1H, OH), 7.24 (s, 1H, ArH), 7.27-7.34 (m, 3H, ArH), 7.40 (dt, J = 7.5, 2.2 Hz, 1H, ArH); ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 13.9, 14.0 (2CH_3), 22.6 (CH_2), 29.1, 29.2 (2CH_2), 29.4 (3CH_2), 31.8 (CH_2), 65.0 (OCH_2), 104.1 (d, J_{FC} = 4.6 Hz, C), 117.4 (d, J_{FC} = 3.7 Hz, C), 122.3 (CH), 124.4 (C), 126.0 (d, J_{FC} = 18.0 Hz, C), 126.3 (CH), 130.1 (d, J_{FC} = 3.0 Hz, CH), 130.7, 131.4 (2CH), 132.5 (d, J_{FC} = 2.4 Hz, C), 146.1 (d, J_{FC} = 15 Hz, C-OH), 147.7 (d, J_{FC} = 239 Hz, C), 148.6 (C), 152.7 (C=O); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -138.1 (ArF); IR (neat): $\widetilde{\nu}$ = 3292 (b), 2954 (w), 2922 (m), 2852 (m), 2224 (w), 1763 (s), 1617 (m), 1433 (s), 1393 (w), 1369 (m), 1243 (s), 1204 (s), 1150 (m), 1094 (m), 994 (m), 898 (w), 763 (m), 694 (m), 579 (w); MS (GC, 70 eV): *m/z* (%): 413 (M^+, 3), 396 (3), 369 (10), 354 (56), 341 (12), 312 (12), 298 (10), 284 (14), 271 (20), 268 (15), 243 (100), 242 (48), 224 (9), 193

(4), 135 (5), 109 (14), 97 (23), 69 (27), 44 (12), 43 (31); HRMS (EI) calcd for $C_{24}H_{28}FNO_4$ [M^+]: 413.19969, found 413.20650 and 413.412190.

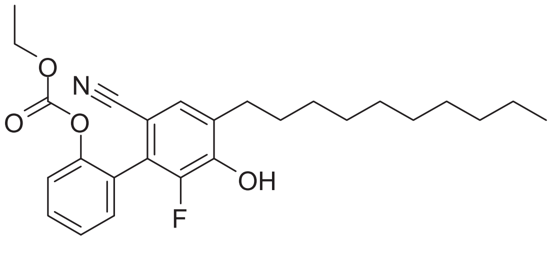
Ethyl 2–(3–decyl–5–oxo-5*H*–chromeno[2,3-*b*]pyridin–2–yl)-2-fluoroacetate (5d):



Chemical Formula: $C_{26}H_{32}FNO_4$
Exact Mass: 441.23

Starting with 3-cyanochromone **4a** (171 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3d** (562mg, 1.30 mmol), CH_2Cl_2 (10.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **5d** was isolated as a white solid (57 mg, 13%), m.p 71-73°C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.79 (t, J = 6.7 Hz, 3H, CH_3), 1.08-1.40 (m, 17H), 1.55-1.75 (m, 2H, CH_2), 2.71-2.87 (m, 2H, CH_2), 4.19-4.35 (m, 2H, OCH_2), 6.06 (d, J_{FH} = 47.5 Hz, CH), 7.34 (t, J = 7.6 Hz, 1H, ArH), 7.51 (d, J = 8.4 Hz, 1H, ArH), 7.70 (dt, J = 7.7, 1.3 Hz, 1H, ArH), 8.21 (dd, J = 7.9, 1.2 Hz, 1H, ArH), 8.51 (s, 1H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 13.1 ($2CH_3$), 21.6, 28.2, 28.3, 28.4, 28.5, 28.6 ($6CH_2$), 29.6 (d, J_{FC} = 1.6 Hz, CH2), 29.9, 30.8, ($2CH_2$), 61.2 (OCH_2), 87.9 (d, J_{FC} = 188.7 Hz, FC), 116.0 (d, J_{FC} = 1.9 Hz, C), 117.5 (CH), 120.5 (C), 123.7 (CH), 125.7 (CH), 134.4 (C), 134.8 (CH), 137.9 (CH), 154.5 (d, J_{FC} = 19.2 Hz, C), 154.8 (C), 156.7 (C), 166.0 (d, J_{FC} = 25.9 Hz, C=O), 176.3 (C=O). ^{19}F NMR (282 MHz, $CDCl_3$): δ = -182.15 (FC); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3052 (w), 2955 (w), 2919 (m), 2850 (w), 1750 (w), 1733(s), 1663 (s), 1602 (s), 1557 (w), 1468 (s), 1436 (m), 1425 (s), 1369 (m), 1315 (m), 1276 (m), 1228 (m), 1152 (m), 1063 (m), 1025 (m), 959 (m), 862 (w), 760 (s), 730 (w), 636 (m) 596 (w); MS (GC, 70 eV): *m/z* (%): 442 (M^++1, 1), 441 (M^+, 4), 384 (2), 368 (4), 337 (24), 336 (100), 328 (30), 315 (3), 294 (2), 254 (12), 242 (16), 210 (4), 55 (1), 43 (3), 29 (3); HRMS (EI) calcd for $C_{26}H_{32}FNO_4$ [M^+]: 441.23099, found 441.231270.

6'-Cyano-4'-decyl-2'-fluoro-3'-hydroxybiphenyl-2-yl ethyl carbonate (6d):

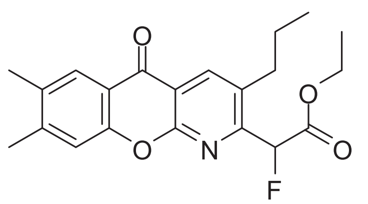


Chemical Formula: $C_{26}H_{32}FNO_4$
Exact Mass: 441.23

Starting with 3-cyanochromone **4a** (171 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3d** (562mg, 1.30 mmol), CH_2Cl_2 (10.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **6d** was isolated as a yellow viscous liquid (335 mg, 76%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.74 (t, J = 6.9 Hz, 3H, CH_3), 1.01-1.19 (m, 17H), 1.42-1.52

(m, 2H, CH_2), 2.51 (t, J = 7.4 Hz, 2H, CH_2), 4.01 (q, J = 7.1 Hz, 2H, OCH_2), 6.39 (brs, 1H, OH), 7.18 (s, 1H, ArH), 7.20-7.27 (m, 3H, ArH), 7.34 (dt, J = 7.6, 2.0 Hz, 1H, ArH); ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 14.0, 14.1 ($2CH_3$), 22.7 (CH_2), 29.1, 29.3 ($2CH_2$), 29.4 ($3CH_2$), 29.5, 29.6, 31.9 ($3CH_2$), 65.0 (OCH_2), 104.1 (d, J_{FC} = 4.4 Hz, C), 117.5 (d, J_{FC} = 3.9 Hz, C), 122.3 (CH), 124.4 (C), 126.0 (d, J_{FC} = 17.7 Hz, C), 126.3 (CH), 130.2 (d, J_{FC} = 3.3 Hz, CH), 130.7, 131.4 (2CH), 132.6 (d, J_{FC} = 2.5 Hz, C), 146.2 (d, J_{FC} = 15 Hz, C-OH), 147.9 (d, J_{FC} = 239 Hz, C), 148.6 (C), 152.8 (C=O). ^{19}F NMR (282 MHz, $CDCl_3$): δ = -138.1 (ArF); IR (neat): $\tilde{\nu}$ = 3292 (b), 2922 (s), 2852 (m), 2225 (w), 1763 (s), 1614 (m), 1459 (m), 1433 (s), 1393 (w), 1369 (m), 1243 (s), 1204 (s), 1152 (m), 1094 (m), 995 (m), 898 (w), 766(m), 695 (w), 579 (w); MS (GC, 70 eV): *m/z* (%): 441 (M^+, 2), 397 (11), 369 (16), 354(17), 340 (23), 312 (14), 298 (14), 284 (14), 284 (22), 271 (32), 268 (16), 243 (100), 242 (52), 224 (10), 193 (3), 135 (3), 109 (6), 97 (10), 69 (13), 44 (12), 43 (26); HRMS (EI) calcd for $C_{26}H_{32}FNO_4$ [M^+]: 441.23099, found 441.231226.

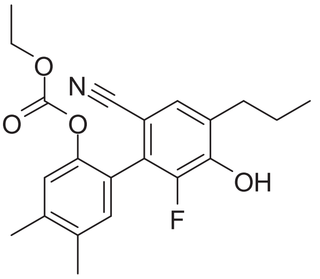
Ethyl 2-(7,8-dimethyl-5-oxo-3-propyl-5*H*-chromeno[2,3-b]pyridin-2-yl)-2-fluoroacetate (5f):



Chemical Formula: $C_{21}H_{22}FNO_4$
Exact Mass: 371.15

Starting with 6,7-dimethyl-3-cyanochromone **4c** (199 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3b** (435mg, 1.30 mmol), CH_2Cl_2 (10.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **5f** was isolated as a yellow solid (52 mg, 14%), mp. 127-129 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.97 (t, J = 7.5 Hz, 3H, CH_3), 1.23 (t, J = 7.2 Hz, 3H, CH_3), 1.60-1.78 (m, 2H, CH_2), 2.30 (s, 3H, CH_3), 2.35 (s, 3H, CH_3), 2.75-2.80 (m, 2H, CH_2), 4.20-4.36 (m, 2H, OCH_2), 6.07 (d, J_{FH} = 47.6 Hz, CH), 7.29 (s, 1H, ArH), 7.95 (s, 1H, ArH), 8.52 (s, 1H, ArH); ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 13.8, 14.1, 19.2, 20.7 ($4CH_3$), 24.1 (CH_2), 32.5(d, J_{FC} =1.4 Hz, CH_2), 62.2 (OCH_2), 87.9 (d, J_{FC} = 188.6 Hz, FC), 117.1 (d, J_{FC} = 1.7 Hz, C), 118.6 (CH), 119.3 (C), 126.3 (CH), 134.4 (C), 134.7 (C), 138.9 (CH), 146.8 (C), 154.3 (C), 155.1 (d, J_{FC} = 18.9 Hz, C), 157.8 (C), 167.1 (d, J_{FC} = 25.8 Hz, C=O), 177.1 (C=O); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -181.96 (FC). IR (ATR, cm^{-1}): $\tilde{\nu}$ = 2955 (m), 2924 (m), 2343 (w), 2142 (w), 1759 (m), 1731(m), 1664 (m), 1622 (s), 1603 (s),1541 (w), 1463 (s), 1422 (s), 14370 (m), 1256 (m), 1210 (s), 1201 (s), 1079 (s), 1014 (m), 874 (m), 799 (m), 676 (w), 580 (w); MS (GC, 70 eV): *m/z* (%): 372 (M^++1, 17), 371 (M^+,72), 357 (23), 356 (100), 343 (6), 322 (6), 298 (17), 297 (6), 296 (7), 283 (7), 282 (35), 278 (17), 238 (7), 149 (2), 91 (4), 77 (3), 65 (2), 29 (9); HRMS (EI) calcd for $C_{21}H_{22}FNO_4$ [M^+]: 371.15274 found 371.152296.

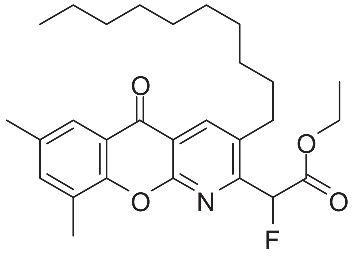
6'-Cyano-2'-fluoro-3'-hydroxy-4,5-dimethyl-4'-propylbiphenyl-2-yl ethyl carbonate (6f):



Chemical Formula: $C_{21}H_{22}FNO_4$
Exact Mass: 371.15

Starting with 6,7-dimethyl-3-cyanochromone **4c** (199 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3b** (435mg, 1.30 mmol), CH_2Cl_2 (10.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **6f** was isolated as a yellow solid (263 mg, 71%), mp. 138-140°C; ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 0.90$ (t, $J = 7.3$ Hz, 3H, CH_3), 1.12 (t, $J = 7.2$ Hz, 3H, CH_3), 1.51-1.64 (m, 2H, CH_2), 2.20 (s, 3H, $ArCH_3$), 2.23 (s, 3H, $ArCH_3$), 2.57 (t, $J = 7.7$ Hz, 2H, CH_2), 4.07 (q, $J = 7.1$ Hz, 2H, OCH_2), 6.20 (brs, 1H, OH), 7.05 (s, 1H, ArH), 7.07 (s, 1H, ArH), 7.23 (s, 1H, ArH); ^{13}C NMR (62.9 MHz, $CDCl_3$): $\delta = 13.8$, 14.0, 19.2, 19.8 (4CH_3), 22.3, (CH_2), 31.3 (d, $J_{FC} = 2.3$ Hz, CH_2), 64.8 (OCH_2), 104.4 (d, $J_{FC} = 4.5$ Hz, C), 117.6, 121.3 (2C), 123.1 (CH), 126.3 (d, $J_{FC} = 17.9$ Hz, C), 130.2 (d, $J_{FC} = 3.1$ Hz, CH), 131.8 (d, $J_{FC} = 2.3$ Hz, C), 131.9 (CH), 134.8 (C), 139.7 (C), 146.1 (d, $J_{FC} = 15$ Hz, C-OH), 147.9 (d, $J_{FC} = 239$ Hz, C), 146.4 (C), 153.0 (C=O). ^{19}F NMR (282 MHz, $CDCl_3$): $\delta = -138.6$ (ArF); IR (neat): $\tilde{\nu} = 3250$ (b), 2931 (w), 2873 (w), 2234 (m), 1759 (s), 1613 (w), 1461 (w), 1440 (m), 1388 (w), 1367 (m), 1239 (s), 1227 (s), 1184 (s), 1094 (m), 989 (m), 878 (m), 779 (m), 658 (w), 572 (w); MS (GC, 70 eV): *m/z* (%): 372 (M^++1, 2), 371 (6), 327 (112), 313(10), 312 (49), 300 (15), 299 (74), 270 (100), 256 (13), 207 (8), 190 (3), 152 (3), 109 (6), 44 (4), 32 (19), 29 (8); HRMS Pos (ESI) calcd for $C_{21}H_{23}FNO_4$ [M+H] $^+$: 372.16056, found 372.16057 and for $C_{21}H_{22}FNaNO_4$ [M+Na] $^+$: 394.14251, found 394.14284.

Ethyl 2-(3-decyl-7,9-dimethyl-5-oxo-5H-chromeno[2,3-b]pyridin-2-yl)-2-fluoroacetate (5g):

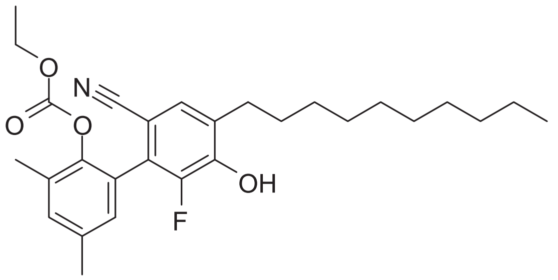


Chemical Formula: $C_{28}H_{36}FNO_4$
Exact Mass: 469.26

Starting with 6,8-dimethyl-3-cyanochromone **4c** (199 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3d** (562 mg, 1.30 mmol), CH_2Cl_2 (10 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **5g** was isolated as yellowish white solid (84 mg, 18 %), mp. 78-80 °C; ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 0.79$ (t, $J = 7.0$ Hz, 3H, CH_3), 1.18-

1.35 (m, 17H, $7CH_2$+$1CH_3$), 1.58-1.66 (m, 2H, CH_2), 2.34 (s, 3H, $ArCH_3$), 2.48 (s, 3H, $ArCH_3$), 2.74-2.80 (m, 2H, CH_2), 4.23-4.31 (m, 2H, OCH_2), 6.06 (d, J_{FH} = 47.7 Hz, CH), 7.34 (s, 1H, ArH), 7.83 (s, 1H, ArH), 8.50 (s, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 13.1 ($2CH_3$), 15.0 (CH_3), 19.7 (CH_3), 21.7 (CH_2), 28.3 (CH_2), 28.4 (CH_2), 28.4 (CH_2), 28.5 (CH_2), 28.6 (CH_2), 29.6 (d, J_{FC} = 1.1 Hz, CH_2), 30.0 (CH_2), 30.9 (CH_2), 61.2 (OCH_2), 87.1 (d, J_{FC} = 189 Hz, FCH), 115.8 (d, J_{FC} = 2.2 Hz, C), 120.1 (C), 122.6 (CH), 126.7 (C), 132.9 (C), 134.1 (C), 137.1 (CH), 137.8 (CH), 151.6 (C), 154.3 (d, J_{FC} = 19.0 Hz, C), 156.7 (C), 166.2 (d, J_{FC} = 25.8 Hz, C=O), 176.7 (C=O); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -181.96 (FC); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 2921 (m), 2852 (m), 1776 (w), 1759 (s), 1671 (s), 1607 (m), 1599 (m), 1564 (w), 1475 (m), 1443 (m), 1426 (s), 1377 (w), 1370 (w), 1305 (m), 1273 (m), 1211 (s), 1196 (s), 1163 (w), 1117 (w), 1073 (m), 1016 (m), 941 (w), 900 (w), 873 (w), 848 (w), 796 (m), 776 (w), 764 (w), 723 (w), 681 (w), 581 (w): MS (GC, 70 eV): *m/z* (%): 470 (M^++1, 2), 469 (M^+, 8), 396 (4), 365 (27), 364 (100), 357 (7), 356 (32), 282 (12), 280 (6), 272 (19), 238 (5), 57 (1), 29 (2); HRMS (EI) calcd for $C_{28}H_{36}FNO_4$ [M^+]: 469.26229 found 469.261562.

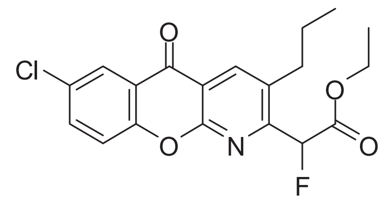
6'-Cyano-4'-decyl-2'-fluoro-3'-hydroxy-3,5-dimethylbiphenyl-2-yl ethyl carbonate (6g):



Chemical Formula: $C_{28}H_{36}FNO_4$
Exact Mass: 469.26

Starting with 6,8-dimethyl-3-cyanochromone **4c** (199 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3d** (562 mg, 1.30 mmol), CH_2Cl_2 (10 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **6g** was isolated as yellowish white solid (295 mg, 63%), mp. 90-92 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.83 (t, J = 6.9 Hz, 3H, CH_3), 1.07 (t, J = 7.1 Hz, 3H, CH_3), 1.22-1.28 (m, 14H, $7CH_2$), 1.55 (p, J = 7.3 Hz, 2H, CH_2), 2.19 (s, 3H, $ArCH_3$), 2.29 (s, 3H, $ArCH_3$), 2.59 (t, J = 8.4 Hz, 2H, CH_2), 4.03 (q, J = 7.1 Hz, 2H, OCH_2), 6.20 (brs, 1H, OH), 6.95 (d, J = 1.7 Hz, 1H, ArH), 7.08 (s, 1H, ArH), 7.24 (d, J = 1.0 Hz, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 12.9 (CH_3), 13.1 (CH_3), 15.1 (CH_3), 19.7 (CH_3), 21.7 (CH_2), 28.1 (CH_2), 28.3 ($3CH_2$), 28.4 (CH_2), 28.5 (CH_2), 28.6 (CH_2), 30.9 (CH_2), 63.8 (OCH_2), 103.5 (d, J_{FC} = 4.5 Hz, C), 116.4 (d, J_{FC} = 3.9 Hz, C), 123.7 (C), 125.4 (d, J_{FC} = 18.1 Hz, C), 128.2 (CH), 129.0 (d, J_{FC} = 3.0 Hz, CH), 129.7 (C), 131.2 (d, J_{FC} = 2.3 Hz, C), 132.2 (CH), 135.0 (C), 144.0 (C), 144.9 (d, J_{FC} = 15 Hz, C-OH), 146.8 (d, J_{FC} = 239 Hz, C), 151.4 (C=O). ^{19}F NMR (282 MHz, $CDCl_3$): δ = -138.16 (ArF); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3294 (br), 2954 (w), 2921 (m), 2853 (m), 2231 (m), 1764 (s), 1615 (w), 1604 (w), 1576 (w), 1503 (w), 1481 (w), 1467 (m), 1446 (m), 1434 (m), 1369 (m), 1330 (w), 1306 (w), 1292 (w), 1250 (s), 1230 (s), 1198 (s), 1147 (m), 1103 (w), 1056 (m), 994 (m), 965 (w), 902 (w), 859 (m), 779 (m), 722 (w), 666 (w), 646 (w), 566 (w): MS (GC, 70 eV): *m/z* (%): 469 (M^+, 2), 411 (9), 410 (34), 397 (13), 396 (10), 382 (12), 381 (6), 380 (21), 368 (20), 354 (17), 340 (12), 326 (13), 312 (15), 299 (20), 298 (14), 296 (13), 285 (32), 284 (74), 271 (100), 270 (26), 268 (4), 252 (11), 250 (8), 43 (7), 29 (7); HRMS (EI) calcd for $C_{28}H_{36}FNO_4$ [M^+]: 469.26229 found 469.261086.

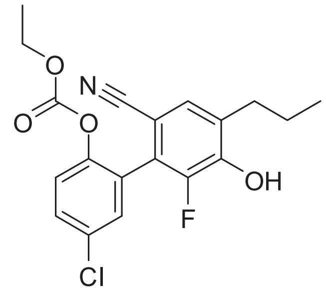
Ethyl 2-(7-chloro-5-oxo-3-propyl-5H-chromeno[2,3-b]pyridin-2-yl)-2-fluoroacetate (5h):



Chemical Formula: $C_{19}H_{17}ClFNO_4$
Exact Mass: 377.08

Starting with 6-chloro-3-cyanochromone **4d** (205 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3b** (434 mg, 1.30 mmol), CH_2Cl_2 (10 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **5h** was isolated as white solid (49 mg, 13 %), mp. 124-126 °C; ^1H NMR (300 MHz, $CDCl_3$): $\delta = 0.97$ (t, $J = 7.3$ Hz, 3H, CH_3), 1.23 (t, $J = 7.2$ Hz, 3H, CH_3), 1.65-1.72 (m, 2H, CH_2), 2.76-2.82 (m, 2H, CH_2), 4.21-4.33 (m, 2H, OCH_2), 6.06 (d, $J_{FH} = 47.7$ Hz, CH), 7.49 (d, $J = 8.9$ Hz, 1H, ArH), 7.64 (dd, $J = 8.9$, 2.6 Hz, 1H, ArH), 8.18 (d, $J = 2.5$ Hz, 1H, ArH), 8.51 (s, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): $\delta = 12.7$ (CH_3), 13.0 (CH_3), 22.9 (CH_2), 31.4 (CH_2), 61.3 (OCH_2), 86.6 (d, $J_{FC} = 188.9$ Hz, FCH), 115.6 (d, $J_{FC} = 1.6$ Hz, C), 119.2 (CH), 121.3 (C), 124.9 (CH), 129.5 (C), 134.4 (C), 134.8 (CH), 138.0 (CH), 153.1(C), 154.9 (d, $J_{FC} = 18.8$ Hz, C), 156.5 (C), 165.8 (d, $J_{FC} = 23.6$ Hz, C=O), 175.2 (C=O); ^{19}F NMR (282 MHz, $CDCl_3$): $\delta = -182.24$ (FC); IR (ATR, cm^{-1}): $\tilde{\nu} = 3084$ (w), 3052 (w), 3003 (w), 2960 (m), 2931 (w), 2872 (w), 1758 (w), 1730 (s), 1667 (s), 1601 (s), 1556 (w), 1469 (s), 1448 (s), 1425 (s), 1371 (m), 1328 (m), 1294 (m), 1274 (s), 1250 (s), 1215 (s), 1203 (m), 1071 (m), 1059 (m), 1027 (m), 957 (m), 865 (m), 839 (m), 791 (m), 720 (s), 637 (m), 544 (m): MS (GC, 70 eV): *m/z* (%): 380 (M^++1, ^{37}Cl, 6), 379 (M^+, ^{37}Cl, 25), 378 (M^++1, ^{35}Cl, 18), 377 (M^+, ^{35}Cl, 71), 364 (33), 363 (19), 362 (100), 349 (5), 304 (18), 290 (23), 288 (41), 284 (18), 283 (7), 282 (7), 278 (13), 277 (17), 276 (35), 275 (7), 274 (9), 272 (22), 270 (11), 269 (13), 256 (7), 244 (9), 29 (14); HRMS (EI) calcd for $C_{19}H_{17}FNO_4Cl$ [M^+, ^{35}Cl]: 377.08247 found 377.082069.

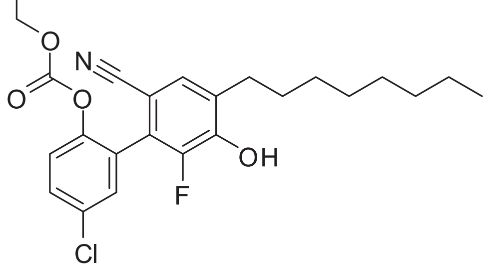
5-Chloro-6'-cyano-2'-fluoro-3'-hydroxy-4'-propylbiphenyl-2-yl ethyl carbonate (6h):



Chemical Formula: $C_{19}H_{17}ClFNO_4$
Exact Mass: 377.08

Starting with 6-chloro-3-cyanochromone **4d** (205 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3b** (434 mg, 1.30 mmol), CH_2Cl_2 (9 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **6h** was isolated as transparent crystals (275 mg, 73 %), mp. 148-150 °C; ^1H NMR (300 MHz, $CDCl_3$): δ = 0.91 (t, J = 7.3 Hz, 3H, CH_3), 1.14 (t, J = 7.1 Hz, 3H, CH_3), 1.59 (sextet, J = 7.4 Hz, 2H, CH_2), 2.58 (t, J = 7.0 Hz, CH_2), 4.10 (q, J = 7.0, 2H, OCH_2), 6.38 (brs, 1H, OH), 7.24-7.27 (m, 2H, ArH), 7.32 (d, J = 1.8 Hz, CH), 7.39 (dd, J = 8.8, 2.2 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 12.7 (CH_3), 12.9 (CH_3), 21.1 (CH_2), 30.3 (d, J_{FC} = 2.2 Hz, CH_2), 64.2 (OCH_2), 102.7 (d, J_{FC} = 4.2 Hz, C), 116.0 (d, J_{FC} = 3.7 Hz, C), 122.6 (CH), 123.6 (d, J_{FC} = 17.4 Hz, C), 124.9 (C), 129.2 (d, J_{FC} = 2.9 Hz, CH), 129.5 (CH), 130.0 (CH), 130.5 (C), 131.7 (d, J_{FC} = 2.5 Hz, C), 145.2 (d, J_{FC} = 14.7 Hz, C-OH), 146.1 (C), 146.7 (d, J_{FC} = 240 Hz, C), 151.4 (C=O); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -138.0 (ArF); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3282 (br), 2965 (w), 2930 (w), 2866 (w), 2235 (w), 1759 (s), 1615 (w), 1604 (w), 1478 (m), 1461 (m), 1389 (w), 1372 (w), 1310 (w), 1261 (m), 1243 (s), 1200 (s), 1154 (s), 1115 (w), 1089 (s), 1050 (s), 995 (m), 978 (m), 885 (m), 833 (m), 720 (m), 662 (m), 637 (br), 582 (w): MS (GC, 70 eV): m/z (%): 377 (M^+, ^{35}Cl, 2), 333 (9), 320 (17), 318 (41), 307 (18), 305 (57), 278 (39), 277 (26), 276 (100), 258 (9), 227 (4), 184 (4), 164 (6), 139 (2), 43 (4), 29 (8); HRMS (EI) calcd for $C_{19}H_{17}FNO_4Cl$ [M^+, ^{35}Cl]: 377.08247 found 377.083324.

5-Chloro-6'-cyano-2'-fluoro-3'-hydroxy-4'-octylbiphenyl-2-yl ethyl carbonate (6i):

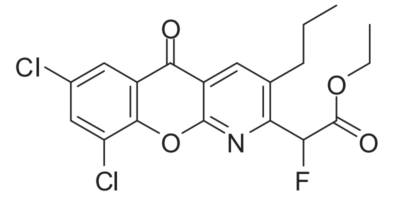


Chemical Formula: $C_{24}H_{27}ClFNO_4$
Exact Mass: 447.16

Starting with 6-chloro-3-cyanochromone **4d** (205 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3c** (526 mg, 1.30 mmol), CH_2Cl_2 (9.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **6i** was isolated as a reddish solid (344 mg, 77 %), mp 121-123°C; ^1H NMR (300 MHz, $CDCl_3$): δ = 0.82 (t, J = 7.0 Hz, 3H, CH_3), 1.13 (t, J_{FC} = 7.1 Hz, 3H, CH_3), 1.18-1.26 (m, 10H, $5CH_2$), 1.49-1.59 (m, 2H, CH_2), 2.59 (dt, J_{HH} = 7.2 Hz, J_{FH} = 2.4 Hz, 2H, CH_2), 4.09 (q, J = 7.1, 2H, OCH_2), 6.38 (brs, 1H, OH), 7.23-7.26 (m, 2H, ArH), 7.31 (d, J = 2.5 Hz, CH), 7.38 (dd, J =

8.7, 2.5 Hz, 1H, ArH); ^{13}C NMR (75.5 MHz, CDCl$_3$): δ = 14.0, 14.1 (2CH$_3$), 22.7 (CH$_2$), 29.1, 29.2 (2CH$_2$), 29.3 (2CH$_2$), 29.4 (d, J_{FC} = 2.3 Hz, CH$_2$), 31.9 (CH$_2$), 65.3 (OCH$_2$), 104.0 (d, J_{FC} = 4.4 Hz, C), 117.1 (d, J_{FC} = 3.8 Hz, C), 123.7 (CH), 124.7 (d, J_{FC} = 17.5 Hz, C), 126.0 (C), 130.3 (d, J_{FC} = 3.0 Hz, CH), 130.7, 131.2 (2CH), 131.6 (C), 133.1 (d, J_{FC} = 2.5 Hz, C), 146.2 (d, J_{FC} = 14.7 Hz, C-OH), 147.2 (C), 147.9 (d, J_{FC} = 240 Hz, C), 152.5 (C=O); ^{19}F NMR (282 MHz, CDCl$_3$): δ = -138.2 (ArF);): δ = -138.0 (ArF); IR (neat): $\tilde{\nu}$ = 3279 (br), 2955 (m), 2924 (m), 2231 (m), 1722 (m), 1752 (m), 1614 (w), 1569 (w), 1484 (m), 1445 (m), 1369 (m), 1262 (s), 1240 (s), 1203 (s), 1154 (s), 1092 (m), 1057 (m), 994 (m), 902 (w), 887 (w), 774 (w), 660 (w), 634 (br), 557 (w); MS (EI, 70 eV): *m/z* (%): 447 (M$^+$, ^{35}Cl, 2), 403 (10), 390 (12), 388 (39), 375 (11), 360 (11), 358 (10), 318 (13), 305 (18), 304 (19), 291 (30), 279 (34), 277 (100), 276 (36), 258 (11), 193 (5), 164 (4), 57 (15), 43 (23), 41 (19); HRMS Neg (ESI), [M-H, ^{35}Cl]$^-$ calcd for $C_{24}H_{26}NClFO_4$ is 446.15471 found 446.15480.

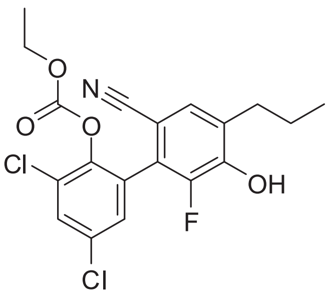
Ethyl 2-(7,9-dichloro-5-oxo-3-propyl-5*H*-chromeno[2,3-b]pyridin-2-yl)-2-fluoroacetate (5k):



Chemical Formula: $C_{19}H_{16}Cl_2FNO_4$
Exact Mass: 411.04

Starting with 6,8-dichloro-3-cyanochromone **4e** (240 mg, 1.0 mmol), Me$_3$SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3b** (435 mg, 1.30 mmol), CH$_2$Cl$_2$ (9.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **5k** was isolated as a white solid (53 mg, 13 %), mp. 120-121°C; ^{1}H NMR (300 MHz, CDCl$_3$): δ = 0.97 (t, J = 7.4 Hz, 3H, CH$_3$), 1.24 (t, J = 7.2 Hz, 3H, CH$_3$), 1.61-1.75 (m, 2H, CH$_2$), 2.69-2.87 (m, 2H, CH$_2$), 4.20-4.36 (m, 2H, OCH$_2$), 6.10 (d, J_{FH} = 47.4 Hz, CFH), 7.74 (d, J = 2.64 Hz, 1H, ArH), 8.07 (d, J = 2.6 Hz, 1H, ArH), 8.49 (s,1H, ArH); ^{13}C NMR (62.9 MHz, CDCl$_3$): δ =13.8 (CH$_3$), 14.0 (CH$_3$), 23.9 (d, J_{FC} = 1.38 Hz, CH$_2$), 32.4 (d, J_{FC} = 2.1 Hz, CH$_2$), 62.4 (OCH$_2$), 88.3 (d, J_{FC} = 189.3 Hz, FC), 116.3 (d, J_{FC} = 1.8 Hz, C), 123.2 (C), 124.6 (CH), 124.7 (C), 130.2 (C), 135.6 (CH), 136.2 (C), 139 (CH), 150.3 (C), 156.5 (d, J = 19.6 Hz, C), 157.2 (C), 166.8 (d, J_{FC} = 25.5 Hz, C=O), 175.8 (C=O); ^{19}F NMR (282 MHz, CDCl$_3$): δ = -182.48 (FC); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3067 (w), 2970 (w), 2935 (w), 1754 (s), 1665 (s), 1608 (m), 1594 (m), 1554 (w), 1463 (m), 1426 (m), 1372 (w), 1228 (m), 1216 (s), 1187 (m), 1093 (w), 1066 (s), 889 (w), 792 (m), 675 (m), 566 (w); MS (GC, 70 eV): *m/z* (%): 415 (M$^+$, ^{37}Cl$_2$, 10), 413 (M$^+$, ^{37}Cl^{35}Cl, 42), 412 (M$^+$+1, ^{35}Cl$_2$, 18), 411 (M$^+$, ^{35}Cl$_2$, 67), 400 (13), 399 (13), 398 (52), 396 (100), 340 (11), 338 (19), 337 (13), 324 (37), 322 (28), 318 (24), 310 (43), 306 (25), 278 (8), 207 (5), 182 (5), 130 (4), 99(4), 29 (26); HRMS (EI) calcd for $C_{19}H_{16}FNO_4Cl_2$ [M^{+}, ^{35}Cl$_2$]: 411.04349 found 411.043394.

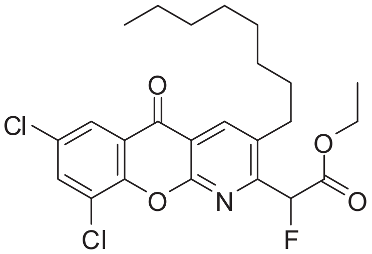
3,5-Dichloro-6'-cyano-2'-fluoro-3'-hydroxy-4'-propylbiphenyl-2-yl ethyl carbonate (6k):



Chemical Formula: $C_{19}H_{16}Cl_2FNO_4$
Exact Mass: 411.04

Starting with 6,8-dichloro-3-cyanochromone **4e** (240 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3b** (435 mg, 1.30 mmol), CH_2Cl_2 (9.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **6k** was isolated as a white solid (300 mg, 73 %), mp. 167-169°C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.91 (t, J = 7.4 Hz, 3H, CH_3), 1.13 (t, J = 7.2 Hz, 3H, CH_3), 1.53-1.63 (m, 2H, CH_2), 2.59 (dt, J_{HH} = 7.2 Hz, J_{FH} = 2.2 Hz, 2H, CH_2), 4.10 (q, J = 7.2, 2H, OCH_2), 6.15 (brs, 1H, OH), 7.23 (d, J = 2.4 Hz, 1H, ArH), 7.27 (d, J = 1.5 Hz, ArH), 7.51 (d, J = 2.5 Hz, 1H, ArH); ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 13.8, 13.9 ($2CH_3$), 22.3 (CH_2), 31.4 (d, J_{FC} = 2.5 Hz, CH_2), 65.8 (OCH_2), 104.1 (d, J_{FC} = 4.0 Hz, C), 116 (d, J_{FC} = 3.8 Hz, C), 123.9 (d, J_{FC} = 17.6 Hz, C), 128.2 (C), 129.2 (C), 129.7 (CH), 130.4 (d, J_{FC} = 3.1 Hz, CH), 131.3 (CH), 132.3 (C), 133.3 (d, J_{FC} = 2.5 Hz, C), 144.1 (C), 146.2 (d, J_{FC} = 14.7 Hz, C-OH), 147.8 (d, J_{FC} = 240 Hz, C), 151.2 (C=O); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -137.7 (ArF); IR (neat): $\widetilde{V}$ = 3263 (br), 2964 (m), 2930 (m), 2230 (m), 1722 (s), 1765 (m), 1610 (w), 1564 (w), 1455 (s), 1388 (m), 1368 (m), 1252 (s), 1217 (s), 1153 (s), 1097 (m), 1053 (m), 991 (m), 899 (w), 883 (w), 859 (m), 781 (m), 650 (w), 561 (w), 535 (w); MS (GC, 70 eV): *m/z* (%): 415 (M^{+}, ^{37}Cl$_2$, 1), 413 (M^{+}, ^{37}Cl^{35}Cl, 5), 412 (M^{+}+1, ^{35}Cl$_2$, 2), 411 (M^{+}, ^{35}Cl$_2$, 8), 382 (5), 380 (5), 354 (16), 352 (26), 341 (55), 339 (80), 324 (14), 313 (16), 312 (55), 311 (28), 310 (100), 296 (10), 292 (10), 207 (29), 133 (3), 96 (3), 44 (17), 40 (9); HRMS (EI) calcd for $C_{19}H_{16}FNO_4Cl_2$ [M^{+}, ^{35}Cl$_2$]: 411.04349 found 411.044397.

Ethyl 2-(7,9-dichloro-3-octyl-5-oxo-5*H*-chromeno[2,3-b]pyridin-2-yl)-2-fluoroacetate (5l):

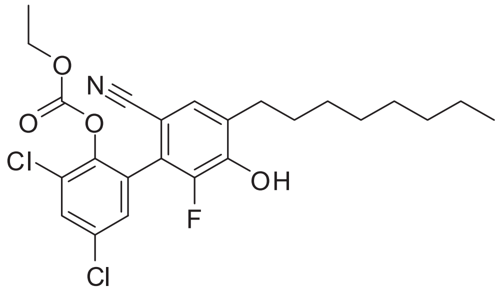


Chemical Formula: $C_{24}H_{26}Cl_2FNO_4$
Exact Mass: 481.12

Starting with 6,8-dichloro-3-cyanochromone **4e** (240 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3c** (526 mg, 1.30 mmol), CH_2Cl_2 (9.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **5l** was isolated as yellowish solid (101 mg, 21 %), mp. 67-68°C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.81 (t, J = 7.0 Hz, 3H,

CH_3), 1.10-1.35 (m, 13H), 1.50-1.71 (m, 2H, CH_2), 2.70-2.88 (m, 2H, CH_2), 4.20-4.36 (m, 2H, OCH_2), 6.08 (d, J_{FH} = 47.3 Hz, 1H, CH), 7.75 (d, J = 2.6 Hz, 1H, ArH), 8.09 (d, J = 2.6 Hz, 1H, ArH), 8.49 (s, 1H, ArH); ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 14.0 ($2CH_3$), 22.6, 29.1, 29.3, 29.4, ($4CH_2$), 30.5 (d, J_{FC} = 1.8 Hz, CH_2), 30.8 (d, J_{FC} = 1 Hz, CH_2), 31.7 (CH_2), 62.4 (OCH_2), 88.3 (d, J_{FC} = 188.9 Hz, FC), 116.3 (d, J_{FC} = 1.8 Hz, C), 123.2 (C), 124.6 (CH), 124.7 (C), 130.2 (C), 135.6 (CH), 136.5 (C), 138.9 (CH), 150.3 (C), 156.5 (d, J_{FC} = 19.4 Hz, C), 157.2 (C), 166.8 (d, J_{FC} = 25.3 Hz, C=O), 175.8 (C=O); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -182.49 (FC); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3067 (w), 2970 (w), 2935 (w), 1754 (s), 1665 (s), 1608 (m), 1594 (m), 1554 (w), 1463 (m), 1426 (m), 1372 (w), 1228 (m), 1216 (s), 1187 (m), 1093 (w), 1066 (s), 889 (w), 792 (m), 675 (m), 566 (w); MS (GC, 70 eV): *m/z* (%): 484 (M^++1, $^{37}Cl^{35}Cl$, 5), 483 (M^+, $^{37}Cl^{35}Cl$, 2), 481 (M^+, $^{35}Cl_2$, 2), 452 (2), 396 (27), 380 (13), 378 (67), 376 (100), 324 (11), 322 (16), 312 (12), 310 (19), 318 (24), 278 (4), 55(2), 29 (9); HRMS (EI) calcd for $C_{24}H_{26}$ O_4NCl_2F [M^+, $^{35}Cl_2$]: 481.12174 found 481.121747.

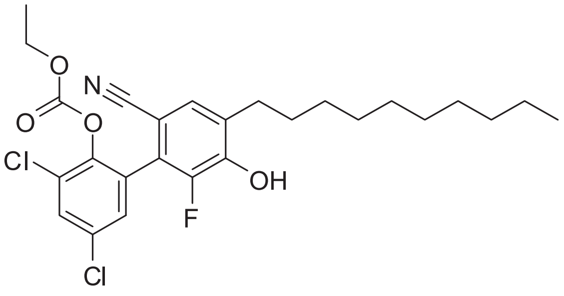
3,5-Dichloro-6'-cyano-2'-fluoro-3'-hydroxy-4'-octylbiphenyl-2-yl ethyl carbonate (6l):



Chemical Formula: $C_{24}H_{26}Cl_2FNO_4$
Exact Mass: 481.12

Starting with 6,8-dichloro-3-cyanochromone **4e** (240 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3c** (526 mg, 1.30 mmol), CH_2Cl_2 (9.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **6l** was isolated as yellowish solid (303 mg, 63 %), mp. 88-90°C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.81 (t, J = 6.8 Hz, 3H, CH_3), 1.11 (t, J = 7.1 Hz, 3H, CH_3), 1.20-1.29 (m, 10H, $5CH_2$), 1.48-1.58 (m, 2H, CH_2), 2.58 (dt, J_{HH} = 7.1 Hz, J_{FH} = 2.1 Hz, 2H, CH_2), 4.09 (q, J = 7.2 Hz, 2H, OCH_2), 6.64 (brs, 1H, OH), 7.22 (d, J = 2.4 Hz, 1H, ArH), 7.25 (d, J = 1.1 Hz, ArH), 7.49 (d, J = 2.5 Hz, 1H, ArH); ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 13.9, 14.0 ($2CH_3$), 22.6, 29.2 ($2CH_2$), 29.3 ($2CH_2$), 29.4 (d, J_{FC} = 2.1 Hz, CH_2), 31.8 (CH_2), 65.8 (OCH_2), 103.8 (d, J_{FC} = 4.0 Hz, C), 116.7 (d, J_{FC} = 3.7 Hz, C), 123.8 (d, J_{FC} = 17.6 Hz, C), 128.3 (C), 129.1 (C), 129.7 (CH), 130.2 (d, J_{FC} = 3.0 Hz, CH), 131.2 (CH), 132.2 (C), 133.7 (d, J_{FC} = 2.6 Hz, C), 144.0 (C), 146.4 (d, J_{FC} = 14.5 Hz, C-OH), 147.8 (d, J_{FC} = 241 Hz, C), 151.2 (C=O); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -137.0 (ArF); IR (neat): $\widetilde{\nu}$ = 3234 (br), 2954 (w), 2922 (m), 2852 (w), 2235 (w), 1774 (s), 1611 (w), 1564 (w), 1461 (s), 1389 (m), 1366 (m), 1251 (s), 1212 (s), 1154 (s), 1100 (m), 1052 (m), 985 (m), 897 (w), 869 (m), 855 (w), 781 (m), 658 (w), 582 (w), 538 (w); MS (GC, 70 eV): *m/z* (%): 481 (M^+, $^{35}Cl_2$, 1), 439 (2), 424 (23), 394 (17), 380 (11), 366 (11), 354 (10), 313 (65), 311 (100), 310 (27), 294 (10), 211 (4), 43 (15), 29 (17); HRMS (EI) calcd for $C_{24}H_{26}FNO_4Cl_2$ [M^+, $^{35}Cl_2$]: 481.12174 found 481.121767.

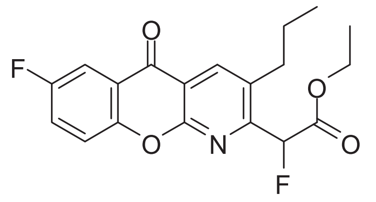
3,5-Dichloro-6'-cyano-4'-decyl-2'-fluoro-3'-hydroxybiphenyl-2-yl ethyl carbonate (6m):



Chemical Formula: $C_{26}H_{30}Cl_2FNO_4$
Exact Mass: 509.15

Starting with 6,8-dichloro-3-cyanochromone **4e** (240 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3d** (562 mg, 1.30 mmol), CH_2Cl_2 (9.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **6m** was isolated as yellowish solid (387 mg, 76 %), mp. 120-121°C; ^1H NMR (300 MHz, $CDCl_3$): δ = 0.81 (t, J = 6.9 Hz, 3H, CH_3), 1.13 (t, J = 7.1 Hz, 3H, CH_3), 1.18-1.30 (m, 14H, $7CH_2$), 1.49-1.59 (m, 2H, CH_2), 2.60 (dt, J_{HH} = 7.2 Hz, J_{FH} = 2.5 Hz, 2H, CH_2), 4.09 (q, J = 7.1 Hz, 2H, OCH_2), 6.14 (brs, 1H, OH), 7.23 (d, J = 2.5 Hz, 1H, ArH), 7.26 (d, J = 1.1 Hz, 1H, ArH), 7.50 (d, J = 2.4 Hz, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 13.9, 14.1 ($2CH_3$), 22.6, 29.0 ($2CH_2$), 29.3 ($2CH_2$), 29.4 ($2CH_2$), 29.5, 29.6, 31.9 ($3CH_2$), 65.8 (OCH_2), 104.1 (d, J_{FC} = 4.0 Hz, C), 116.7 (d, J_{FC} = 3.8 Hz, C), 123.8 (d, J_{FC} = 17.8 Hz, C), 128.2, 129.1 (2C), 129.7 (CH), 130.3 (d, J_{FC} = 3.0 Hz, CH), 131.3 (CH), 132.2 (C), 133.6 (d, J_{FC} = 2.4 Hz, C), 144.0 (C), 146.1 (d, J_{FC} = 14.5 Hz, C-OH), 147.7 (d, J_{FC} = 241 Hz, C), 151.1 (C=O); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -137.6 (ArF); IR (neat): $\tilde{\nu}$ = 3322 (br), 2951 (m), 2920 (s), 2852 (m), 2228 (w), 1759 (m), 1681 (w), 1567 (w), 1464 (m), 1453 (m), 1369 (m), 1332 (w), 1251 (m), 1214 (s), 1154 (m), 1095 (w), 1053 (m), 990 (m), 864 (w), 849 (w), 781 (m), 687 (w), 576 (w), 565 (w); MS (GC, 70 eV): *m/z* (%): 511 (M^+, $^{37}Cl^{35}Cl$, 4), 510 (M^++1, $^{35}Cl_2$, 3), 509 (M^+, $^{35}Cl_2$, 6), 452 (15), 448 (10), 436 (13), 424 (14), 422 (51), 420 (63), 408 (17), 394 (15), 380 (13), 366 (19), 354 (18), 313 (60), 311 (100), 310 (37), 294 (10), 211 (3), 43 (27), 29 (49); HRMS Pos (ESI) calcd for $C_{26}H_{31}FNO_4Cl_2$ [M+H, $^{35}Cl_2$]$^+$calcd is 510.16087 found 510.16156 and [M+Na]$^+$ calcd is 532.14281 found 532.1436 and exact ion mass is 509.1536.

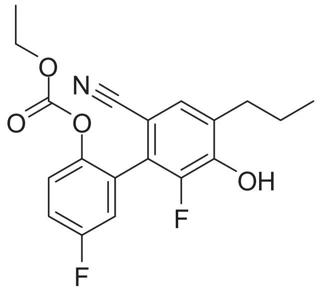
Ethyl 2-fluoro-2-(7-fluoro-5-oxo-3-propyl-5H-chromeno[2,3-b]pyridin-2-yl)acetate (5o):



Chemical Formula: $C_{19}H_{17}F_2NO_4$
Exact Mass: 361.11

Starting with 6-fluoro-3-cyanochromone **4f** (189 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3b** (434 mg, 1.30 mmol), CH_2Cl_2 (9 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **5o** was isolated as a white solid (60 mg, 16 %), mp. 127-129 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.97 (t, J = 7.3Hz, 3H, CH_3), 1.23 (t, J = 7.2 Hz, 3H, CH_3), 1.65-1.73 (m, 2H, CH_2), 2.76-2.82 (m, 2H, CH_2), 4.21-4.33 (m, 2H, OCH_2), 6.06 (d, J_{FH} = 47.4 Hz, CH), 7.40-7.47 (m, 1H, ArH), 7.53 (dd, J = 9.2, 4.2 Hz, 1H, ArH), 7.86 (dd, J= 8.0, 3.0 Hz, 1H, ArH), 8.51 (s, 1H, ArH); ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 12.75 (CH_3), 13.0 (CH_3), 22.9 (d, J_{FC} = 0.8 Hz, CH_2), 31.4 (d, J_{FC} = 1.4 Hz, CH_2), 61.2 (OCH_2), 86.6 (d, J_{FC} = 188.7 Hz, FCH), 110.5 (d, J_{FC} = 24.2 Hz, CH), 115.1 (C), 119.6 (d, J_{FC} = 7.6 Hz, CH), 121.4 (d, J_{FC} = 7.3 Hz, C), 122.8 (d, J_{FC} = 25.1 Hz, CH), 134.3 (C),137.9 (CH), 150.9 (d, J_{FC} = 1.6 Hz, C), 154.9 (d, J_{FC} = 18.9 Hz, C), 156.6 (C), 158.1 (d, J_{FC} = 247 Hz, ArFC), 165.8 (d, J_{FC} = 25.6 Hz, C=O), 175.6 (d, J_{FC} = 2.1 Hz, C=O); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -115.7 (ArF), -182.3 (FC); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3090 (w), 3053 (w), 3000 (w), 2963 (m), 2932 (w), 2873 (w), 1732 (s), 1668 (s), 1623 (w), 1604 (m), 1562 (w), 1483 (s), 1455 (s), 1424 (s), 1370 (w), 1326 (m), 1275 (s), 1253 (s), 1207 (m), 1186 (m), 1144 (m), 1072 (m), 1057 (m), 1027 (m), 990 (w), 959 (m), 882 (m), 840 (m), 787 (m), 777 (s), 740 (s), 701 (w), 636 (m), 560 (m): MS (GC, 70 eV): *m/z* (%): 363 (M^++2, 2), 362 (M^++1, 16), 361 (M^+, 81), 347 (19), 343 (2), 341 (5), 318 (6), 288 (18), 286 (11), 273 (12), 272 (49), 268 (24), 261 (14), 260 (41), 259 (11), 256 (21), 254 (12), 253 (18), 228 (7), 29 (15); HRMS (EI) calcd for $C_{19}H_{17}F_2NO_4$ [M^+]: 361.11202 found 361.110966.

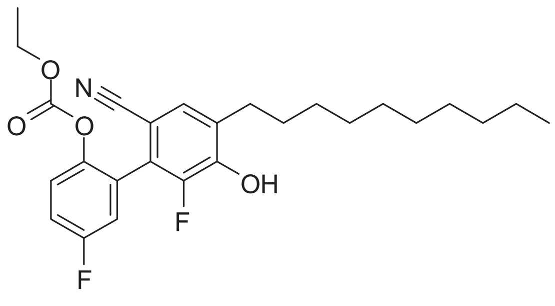
6'-Cyano-2',5-difluoro-3'-hydroxy-4'-propylbiphenyl-2-yl ethyl carbonate (6o):



Chemical Formula: $C_{19}H_{17}F_2NO_4$
Exact Mass: 361.11

Starting with 6-fluoro-3-cyanochromone **4f** (189 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3b** (434 mg, 1.30 mmol), CH_2Cl_2 (9 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **6o** was isolated as transparent crystals (272 mg, 75%), mp. 143-144 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.89 (t, J = 7.2 Hz, 3H, CH_3), 1.11 (t, J = 7.2 Hz, 3H, CH_3), 1.56 (sextet, J = 7.4 Hz, 2H, CH_2), 2.56 (t, J = 7.6 Hz, 2H, CH_2), 4.06 (q, J = 7.0 Hz, 2H, OCH_2), 6.44 (brs, 1H, OH), 7.02-7.12 (m, 2H, ArH), 7.18-7.27 (m, 2H, ArH); ^{13}C NMR (75.49 MHz, $CDCl_3$): δ = 12.6 (CH_3), 12.8 (CH_3), 21.1 (CH_2), 30.2 (d, J_{FC} = 2.3 Hz, CH_2), 64.1 (OCH_2), 102.6 (d, J_{FC} = 4.1 Hz, C), 116.0 (d, J_{FC} = 3.7 Hz, C), 116.2 (d, J_{FC} = 23.8 Hz, CH), 116.9 (d, J_{FC} = 23.8 Hz, CH), 122.8 (d, J_{FC} = 9.1 Hz, CH), 123.7, (d, J_{FC} = 17 Hz, C), 124.9 (d, J_{FC} = 8 Hz, C), 129.2 (d, J_{FC} = 3.5 Hz, CH), 131.7 (d, J_{FC} = 2.4 Hz, C), 143.5 (d, J_{FC} = 3 Hz, C), 145.2 (d, J_{FC} = 15 Hz, C-OH), 146.7 (d, J_{FC} = 240 Hz, C), 151.7 (C=O), 158.7 (d, J_{FC} = 246 Hz, C); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -115.40, -137.98 (ArF); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3291 (br), 2965 (w), 2932 (w), 2873 (w), 2234 (w), 1759 (s), 1612 (w), 1589 (w), 1574 (w), 1512 (w), 1483 (m), 1465 (m), 1406 (m), 1372 (m), 1308 (m), 1257 (m), 1239 (s), 1223 (s), 1179 (s), 1137 (m), 1104 (m), 1093 (m), 1049 (m), 991 (m), 975 (m), 894 (m), 875 (m), 835 (m), 790 (m), 778 (m), 635 (br), 589 (w): MS (GC, 70 eV): *m/z* (%): 361 (M$^+$, 2), 331 (15), 330 (64), 317 (19), 300 (26), 288 (11), 275 (33), 274 (100), 261 (49), 260 (88), 242 (14), 212 (4), 211 (14), 202 (5), 195 (3), 182 (5), 41 (5), 29 (13); HRMS (EI) calcd for $C_{19}H_{17}F_2NO_4$ [M$^+$]: 361.11202 found 361.111304.

6'-Cyano-4'-decyl-2',5-difluoro-3'-hydroxybiphenyl-2-yl ethyl carbonate (6p):



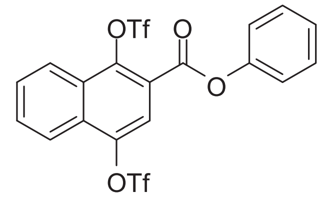
Chemical Formula: $C_{26}H_{31}F_2NO_4$
Exact Mass: 459.22

Starting with 6-flouro-3-cyanochromone **4f** (184 mg, 1.0 mmol), Me_3SiOTf (288 mg, 0.23 mL, 1.30 mmol), **3d** (562 mg, 1.30 mmol), CH_2Cl_2 (9.0 mL), EtOH (10 mL), and triethylamine (202 mg, 0.28 mL, 2 mmol), **6p** was isolated as solid (353 mg, 77 %), mp. 134-135°C**;** ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.80 (t, *J* = 6.8 Hz, 3H, CH_3), 1.11 (t, *J* = 7.0 Hz, 3H, CH_3), 1.17-1.30 (m, 14H, $7CH_2$), 1.48-1.58 (m, 2H, CH_2), 2.58 (dt, J_{HH} = 7.2 Hz, J_{FH} = 2.4 Hz, 2H, CH_2), 4.07 (q, *J* = 7.1 Hz, 2H, OCH_2), 6.53 (brs, 1H, OH), 7.01-7.13 (m, 2H, ArH), 7.23-7.27 (m, 2H, ArH); ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 13.9, 14.1 ($2CH_3$), 22.7, 29.1, 29.2, 29.3 ($4CH_2$), 29.4 ($2CH_2$), 29.5, 29.6, 31.9 ($3CH_2$), 65.1 (OCH_2), 103.8 (d, J_{FC} = 4.2 Hz, C), 117.1 (d, J_{FC} = 3.3 Hz, C), 117.4 (d, J_{FC} = 23.3 Hz, CH), 118.1 (d, J_{FC} = 24.5 Hz, CH), 123.9 (d, J_{FC} = 8.7 Hz, CH), 124.8, (d, J_{FC} = 17.6 Hz, C), 126.1 (d, J_{FC} = 8.8 Hz, C), 130.2 (d, J_{FC} = 2.8 Hz, CH), 133.1 (d, J_{FC} = 2.4 Hz, C), 144.7 (d, J_{FC} = 3.1 Hz, C), 146.3 (d, J_{FC} = 14.7 Hz, C-OH), 147.8 (d, J_{FC} = 240 Hz, C), 152.8 (C=O), 159.8 (d, J_{FC} = 246 Hz, C); ^{19}F NMR (282 MHz, $CDCl_3$): δ = -115.4, -138.0 (ArF); IR (neat): $\widetilde{\nu}$ = 3310 (br), 2923 (m), 2853 (w), 2228 (w), 1764 (m), 1612 (w), 1593 (w), 1461 (m), 1405 (w), 1369 (m), 1239 (s), 1182 (s), 1137 (w), 995 (m), 874 (w), 835 (w), 776 (m), 688 (w), 591 (w), 562 (w); MS (GC, 70 eV): *m/z* (%): 460 (M^++1, 3), 459 (M^+, 10), 400 (28), 398 (12), 372 (18), 370 (60), 358 (20), 344 (18), 330 (15), 316 (16), 302 (28), 288 (19), 274 (83), 261 (100), 242 (13), 184 (5), 43 (17), 29 (35); HRMS Neg (ESI) calcd for $C_{26}H_{30}F_2NO_4$ $[M\text{-}H]^-$ calcd is 458.21484 found 458.21493 and $[2M\text{-}H]^-$ calcd is 917.43695 found 917.43757 and exact ion mass found as 459.22211.

Procedure for synthesis of Phenyl 1,4-bis(trifluoromethylsulfonyloxy)-2-naphthoate (8):

To a solution of **7** (1.0 equiv.) in CH_2Cl_2 (10 mL per 1 mmol of **7**), was added pyridine (4.0 equiv.) at – 78 °C under an argon atmosphere. After stirring for 10 min, Tf_2O (2.4 equiv.) was added at -78 °C. The mixture was allowed to warm up to 0 °C and stirred for 4 h. The reaction mixture was filtered and the filtrate was concentrated in vacuo. The product of the reaction mixture was isolated by rapid column chromatography (flash silica gel, heptanes/EtOAc).

Phenyl 1,4-bis(trifluoromethylsulfonyloxy)-2-naphthoate (8) :



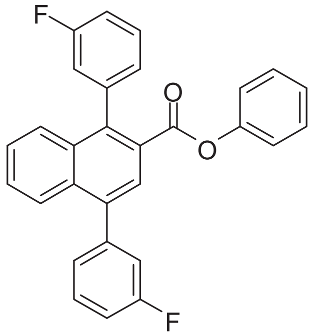
Chemical Formula: $C_{19}H_{10}F_6O_8S_2$
Exact Mass: 543.97

Starting with **7** (2800mg, 10mmol), pyridine (3.2ml, 40 mmol), CH_2Cl_2, -78 °C, 10 min, 2), Tf_2O (4.0ml, 24mmol), -78°C → 0°C, **8** was isolated as white powder (4515mg, 83%), mp. 100-101°C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.20-7.27 (m, 3H, ArH), 7.36-7.41 (m, 2H, ArH), 7.75-7.85 (m, 2H, ArH), 8.08 (s, 1H, ArH), 8.12 (dd, *J* = 7.1, 1.8 Hz, 1H, ArH), 8.24 (d, *J* = 7.9 Hz, 1H, ArH); ^{13}C NMR (62.90 MHz, $CDCl_3$): δ = 118.5 (CH), 118.6 (q, $^1J_{CF}$ = 321 Hz, CF_3), 118.7 (q, $^1J_{CF}$ = 321 Hz, CF_3), 121.2 (C), 121.4 (2CH), 121.5 (CH), 123.1 (CH), 126.6 (CH), 127.9 (C), 129.6 (C), 129.7 (2CH), 129.9 (CH), 131.4 (CH), 144.0 (C), 144.2 (C), 150.2 (C), 161.9 (C=O); ^{19}F NMR (282.4 MHz. $CDCl_3$): δ = -72.27 (3F, CF_3), -72.96 (3F, CF_3); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3068 (w), 1733(m), 1589 (w), 1482 (w), 1427 (s), 1358 (m), 1347 (m), 1247 (m), 1203 (s), 1130 (s), 1045 (m), 1018 (m), 936 (m), 873 (s), 761 (s), 641 (s), 597 (s); MS (EI, 70 eV): *m/z* (%): 544 (M^+, 10), 453 (16), 452 (22), 451 (100), 318 (64), 234 (3), 186 (19), 185 (97), 157 (47), 129 (16), 101 (18), 75 (5), 69 (8), 64 (9), 51 (3); HRMS (EI) calcd for $C_{19}H_{10}O_8F_6S_2$ $[M^+]$: 543.97158, found 543.970512.

General Procedure for synthesis of 10a-h and 11a-f:

A 1,4-dioxane solution (4 mL per 0.5 mmol of **8**) of **8**, K_3PO_4, $Pd(PPh_3)_4$ and arylboronic acid **9** was stirred at 110 or 95 °C for 8 h. After cooling to 20 °C, a saturated aqueous solution of NH_4Cl was added. The organic and the aqueous layer were separated and the latter was extracted with CH_2Cl_2. The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in vacuo. The residue was purified by column chromatography.

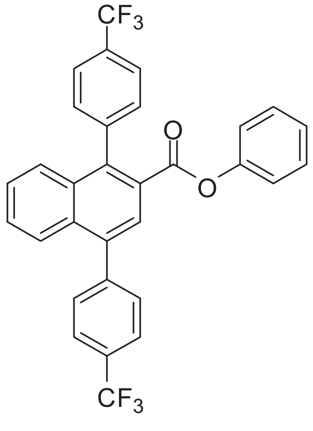
Phenyl 1,4-bis(3-fluorophenyl)-2-naphthoate (10a):



Chemical Formula: $C_{29}H_{18}F_2O_2$
Exact Mass: 436.13

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9a** (168 mg, 1.2 mmol) and 1,4-dioxane (4 mL), **10a** was isolated as colorless crystals (185 mg, 85%), mp. 143-144 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.75-6.79 (m, 2H, ArH), 7.05-7.28 (m, 9H, ArH), 7.39-7.49 (m, 4H, ArH), 7.58 (dd, J = 8.1, 1.0 Hz, 1H, ArH), 7.87 (dd, J = 8.1, 1.0 Hz, 1H, ArH), 7.95 (s, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 114.9 (d, J_{CF} = 21.0 Hz, CH), 115.0 (d, J_{CF} = 21.0 Hz, CH), 117.3 (d, J_{CF} = 21.8 Hz, CH), 117.4 (d, J_{CF} = 21.8 Hz, CH), 121.5 (2CH), 125.9 (d, J_{CF} = 3.0 Hz, CH), 126.0 (d, J_{CF} = 3.0 Hz, CH), 126.1 (CH), 126.2 (CH), 126.6 (CH), 127.2 (CH+C), 128.2 (CH), 128.4 (CH), 129.6 (2CH), 129.9 (d, J_{CF} = 8.4 Hz, CH), 130.3 (d, J_{CF} = 8.4 Hz, CH), 133.0 (C), 133.3 (C), 139.6 (d, J_{CF} = 1.8 Hz, C), 140.4 (d, J_{CF} = 1.8 Hz, C), 141.2 (d, J_{CF} = 8.0 Hz, C), 142.1 (d, J_{CF} = 8.0 Hz, C), 150.8 (C), 162.8 (d, J_{CF} = 247 Hz, CF), 162.9 (d, J_{CF} = 247 Hz, CF), 166.5 (C=O); ^{19}F NMR (282.40 MHz, $CDCl_3$): δ = -112.83 (ArF), -113.26 (ArF); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3070 (w), 2924 (w), 2852 (w), 1750 (m), 1579 (m), 1434 (m), 1341 (w), 1251 (m), 1190 (s), 1173 (s), 1142 (s), 1094 (s), 868 (s), 762 (s), 686 (s), 570 (w); MS (GC, 70 eV): *m/z* (%): 436 (M^+, 2), 344 (26), 343 (100), 312 (12), 294 (14), 220 (6), 156 (1), 39 (1); HRMS (EI) calcd for $C_{29}H_{18}O_2F_2$ [M^+]: 436.12694 found 436.12754.

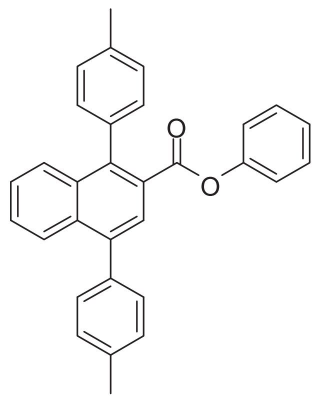
Phenyl 1,4-bis(4-(trifluoromethyl)phenyl)-2-naphthoate (10b):



Chemical Formula: $C_{31}H_{18}F_6O_2$
Exact Mass: 536.12

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9b** (228 mg, 1.2 mmol) and 1,4-dioxane (4 mL), **10b** was isolated as colorless crystals (214 mg, 80%), mp. 178-180 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.68-6.72 (m, 2H, ArH), 7.03-7.73 (m, 14H, ArH), 7.80-7.83 (m, 1H, ArH), 7.99 (s, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 121.3 (2CH), 124.3 (q, J_{CF} = 272 Hz, C), 124.4 (q, J_{CF} = 272 Hz, C), 125.4 (q, J_{CF} = 3.7 Hz, 2CH), 125.7 (q, J_{CF} = 3.7 Hz, 2CH), 126.1 (CH), 126.2 (CH), 126.8 (CH), 127.1 (C), 127.4 (CH), 128.2 (CH), 128.7 (CH), 129.6 (2CH), 130.2 (q, J_{CF} = 32.4 Hz, C), 130.3 (q, J_{CF} = 32.4 Hz, C), 130.4 (2CH), 130.6 (2CH), 133.0 (C), 133.3 (C), 139.7 (C), 140.9 (C), 143.0 (C), 143.6 (C), 150.7 (C), 166.1 (C=O); ^{19}F NMR (282.40 MHz, $CDCl_3$): δ = -62.40 ($ArCF_3$), -62.41 ($ArCF_3$); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3078 (w), 2923 (w), 2853 (w), 1715 (m), 1591 (w), 1403 (w), 1323 (s), 1241 (m), 1220 (m), 1157 (s), 1102 (s), 1065 (s), 928 (w), 832 (m), 765 (s), 688 (m), 600 (m); MS (GC, 70 eV): *m/z* (%): 536 (M$^+$, 1), 444 (29), 443 (100), 346 (13), 276 (7), 162 (1), 65 (3); HRMS (EI) calcd for C_{31} H_{18} O_2 F_6 [M$^+$]: 536.12055 found 536.12140.

Phenyl 1,4-di*p*-tolyl-2-naphthoate (10c):

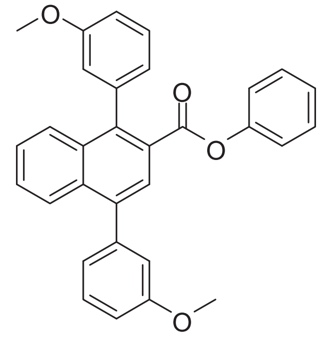


Chemical Formula: $C_{31}H_{24}O_2$
Exact Mass: 428.18

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9c** (163 mg, 1.2 mmol) and 1,4-dioxane (4 mL), **10c** was isolated as colorless crystals (163 mg, 76%), mp. 120-122 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.37 (s, 3H, CH_3), 2.38 (s, 3H, CH_3), 6.70-6.74 (m, 2H, ArH), 7.02-7.08 (m, 1H, ArH), 7.15-7.26 (m, 8H, ArH), 7.31-7.43 (m, 4H, ArH), 7.65 (dd, *J* = 8.1, 1.2 Hz, 1H, ArH), 7.89 (s, 1H, ArH), 7.91 (dd, *J* = 7.6, 1.2 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 21.3 (CH_3), 21.4 (CH_3), 121.5 (2CH), 125.7 (CH), 126.3 (2CH), 126.5 (CH), 127.5 (C), 127.6 (CH), 128.3 (CH), 128.9 (2CH), 129.2 (2CH), 129.3 (2CH), 129.9 (2CH), 130.0 (2CH), 133.2 (C), 133.4 (C), 135.9 (C), 137.0 (C), 137.2 (C), 137.5 (C), 140.2 (C), 141.0 (C), 150.8 (C), 167.1 (C=O); IR $\tilde{\nu}$ = IR (ATR, cm^{-1}):

$\tilde{\nu}$ = 3022 (w), 2921 (w), 2865 (w), 1711(s), 1591 (w), 1511 (w), 1485 (m), 1378 (m), 1367 (m), 1241 (s), 1220 (s), 1192 (s), 1099 (m), 1020 (m), 926 (m), 814 (s), 746 (s), 687 (m), 595 (m); MS (EI, 70 eV): *m/z* (%): 428 (M^+, 3), 336 (27), 335 (100), 292 (7), 289 (6), 276 (6), 145 (3), 65 (2); HRMS (EI) calcd for $C_{31}H_{24}O_2$ [M^+]: 428.17708 found 428.177832.

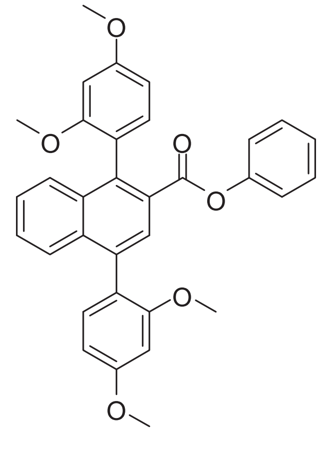
Phenyl 1,4-bis(3-methoxyphenyl)-2-naphthoate (10d):



Chemical Formula: $C_{31}H_{24}O_4$
Exact Mass: 460.17

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9d** (182 mg, 1.2 mmol) and 1,4-dioxane (4 mL), **10d** was isolated as colorless crystals (149 mg, 65 %), mp. 118-120 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.73 (s, 3H, OCH_3), 3.79 (s, 3H, OCH_3), 6.73-6.76 (m, 2H, ArH), 6.92-7.23 (m, 9H, ArH), 7.32-7.47 (m, 4H, ArH), 7.68 (dd, *J* = 8.1, 1.1 Hz, 1H, ArH), 7.92 (s, 1H, ArH), 7.93 (dd, *J* = 8.3, 1.0 Hz, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 55.5 (OCH_3), 55.6 (OCH_3), 113.5 (CH), 113.6 (CH), 115.7 (CH), 115.8 (CH), 121.6 (2CH), 122.7 (2CH), 125.9 (CH), 126.3 (CH), 126.4 (CH), 126.8 (CH), 127.4 (C), 127.9 (CH), 128.3 (CH), 129.3 (CH), 129.4 (2CH), 129.6 (CH), 133.0 (C), 133.4 (C), 140.3 (C), 140.4 (C), 141.0 (C), 141.4 (C), 150.9 (C), 159.6 (C), 159.8 (C), 167.1 (C=O); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3064 (w), 2934 (w), 2833 (w), 1731(m), 1575 (m), 1485 (m), 1377 (m), 1252 (m), 1217 (s), 1186 (s), 1098 (s), 1040 (s), 925 (w), 850 (m), 762 (s), 686 (s), 558 (w); MS (EI, 70 eV): *m/z* (%): 460 (M^+, 15), 369 (13), 368 (81), 367 (100), 366 (57), 352 (14), 324 (18), 263 (11), 252 (11), 94 (14), 65 (7); HRMS (EI) calcd for $C_{31}H_{24}O_4$ [M^+]: 460.16691 found 460.16645.

Phenyl 1,4-bis(2,4-dimethoxyphenyl)-2-naphthoate (10e):

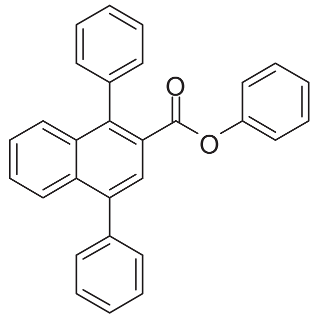


Chemical Formula: $C_{33}H_{28}O_6$
Exact Mass: 520.19

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9e** (218 mg, 1.2 mmol) and 1,4-dioxane (4 mL), **10e** was isolated as colorless crystals (146 mg, 56%), mp. 175-177 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.73 (s, 3H, OCH_3), 3.81 (s, 3H, OCH_3), 3.84 (s, 3H, OCH_3), 3.85 (s, 3H, OCH_3), 6.71-6.75 (m, 2H, ArH), 6.89-7.06 (m, 7H, ArH), 7.14-7.20 (m, 2H, ArH), 7.32-7.44 (m, 2H, ArH), 7.70 (dd, *J* = 8.1, 1.3 Hz, 1H, ArH), 7.86 (s, 1H, ArH), 7.93 (dd, *J* = 8.0, 1.3

Hz, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 56.1 ($4OCH_3$), 111.1 (CH), 111.3 (CH), 113.4 (CH), 113.6 (CH), 121.4 (2CH), 122.5 (2CH), 125.8 (CH), 126.1 (CH), 126.3 (CH), 126.7 (CH), 127.7 (CH), 127.9 (C), 128.2 (CH), 129.4 (2CH), 131.3 (C), 132.6 (C), 133.3 (C), 133.5 (C), 140.2 (C), 140.3 (C), 148.7 (C), 148.8 (2C), 148.9 (C), 150.8 (C), 167.3 (C=O); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3011 (w), 2958 (w), 2836 (w), 1747 (m), 1609 (m), 1505 (m), 1486 (w), 1376 (w), 1304 (m), 1208 (s), 1189 (s), 1157 (s), 1092 (m), 1030 (m), 926 (w), 828 (m), 767 (m), 687 (m), 586 (w). MS (EI, 70 eV): *m/z* (%): 520 (M^+, 15), 428 (55), 427 (100), 412 (10), 396 (10), 384 (5), 311 (2), 283 (1), 239 (1), 206 (3), 94 (3); HRMS (EI) calcd for $C_{33}H_{28}O_6$ [M^+]: 520.18804 found 520.18795.

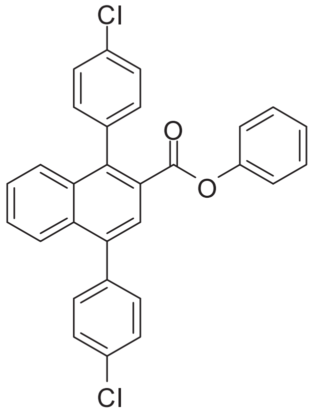
Phenyl 1,4-diphenyl-2-naphthoate (10f):



Chemical Formula: $C_{29}H_{20}O_2$
Exact Mass: 400.15

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9f** (146 mg, 1.2 mmol) and 1,4-dioxane (4 mL), **10f** was isolated as colorless crystals (146 mg, 73%), mp. 96-97 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.64-6.80 (m, 2H, ArH), 7.00-7.17 (m, 3H, ArH), 7.28-7.48 (m, 12H, ArH), 7.60 (dd, *J* = 8.2, 1.0 Hz, 1H, ArH), 7.88 (dd, *J* = 8.6, 1.0 Hz, 1H, ArH), 7.90 (s, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 121.5 (2CH), 125.8 (CH), 126.4 (CH), 126.5 (CH), 126.8 (CH), 127.6 (C), 127.8 (CH), 127.9 (2CH), 128.3 (2CH), 128.4 (CH), 128.6 (2CH), 129.4 (2CH), 130.1 (2CH), 130.2 (2CH), 133.2 (C), 133.4 (C), 139.1 (C), 140.0 (C), 140.5 (C), 141.1 (C), 150.8 (C), 167.2 (C=O); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3027 (w), 2923 (w), 2850 (w), 1731 (m), 1590 (w), 1490 (w), 1379 (w), 1238 (m), 1210 (m), 1187 (s), 1096 (s), 1029 (w), 931 (w), 760 (m), 698 (s), 686 (s); MS (GC, 70 eV): *m/z* (%): 400 (M^+, 2), 308 (25), 307 (100), 278 (11), 277 (13), 276 (13), 202 (4), 138 (2), 65 (2); HRMS (EI) calcd for $C_{29}H_{20}O_2$ [M^+]: 400.14578 found 400.14612.

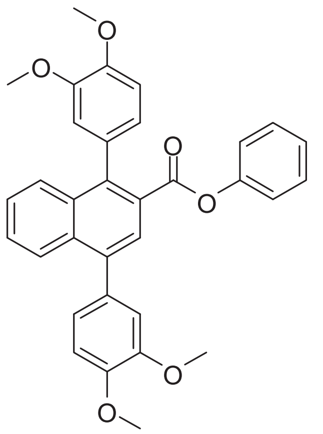
Phenyl 1,4-bis(4-chlorophenyl)-2-naphthoate (10g):



Chemical Formula: $C_{29}H_{18}Cl_2O_2$
Exact Mass: 468.07

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9g** (187 mg, 1.2 mmol) and 1,4-dioxane (4 mL), **10g** was isolated as colorless crystals (185 mg, 79%), mp. 170-172 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.72-6.76 (m, 2H, ArH), 7.02-7.26 (m, 5H, ArH), 7.32-7.45 (m, 8H, ArH), 7.53 (dd, *J* = 8.4, 1.0 Hz, 1H, ArH), 7.82 (dd, *J* = 8.3, 1.0 Hz, 1H, ArH), 7.91 (s, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 121.4 (2CH), 126.0 (CH), 126.1 (CH), 126.6 (CH), 127.1 (CH), 127.2 (C), 128.2 (CH), 128.3 (CH), 128.6 (2CH), 128.9 (2CH), 129.5 (2CH), 131.3 (2CH), 131.5 (2CH), 133.2 (C), 133.3 (C), 133.9 (C), 134.1 (C), 137.4 (C), 138.3 (C), 139.5 (C), 140.6 (C), 150.7 (C), 166.5 (C=O); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3063 (w), 2919 (w), 2850 (w), 1716 (m), 1590 (w), 1488 (m), 1376 (m), 1369 (m), 1244 (m), 1218 (s), 1192 (s), 1087 (s), 1013 (m), 907 (m), 823 (s), 764 (s), 740 (s), 690 (s), 570 (m); MS (GC, 70 eV): *m/z* (%): 470 (M^+, $^{37}Cl^{35}Cl$, 3), 468 (M^+, $^{35}Cl_2$, 3), 378 (16), 377 (67), 376 (27), 375 (100), 342 (11), 340 (35), 312 (21), 277 (11), 276 (33), 138 (7), 65 (5); HRMS (EI) calcd for C_{29} H_{18} O_2Cl_2 [M^+, $^{35}Cl_2$]: 468.06784 found 468.06884.

Phenyl 1,4-bis(3,4-dimethoxyphenyl)-2-naphthoate (10h):

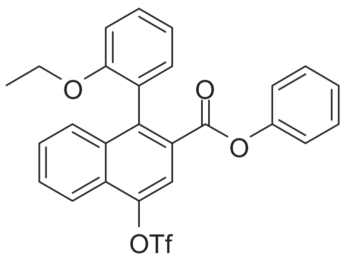


Chemical Formula: $C_{33}H_{28}O_6$
Exact Mass: 520.19

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9h** (218 mg, 1.2 mmol) and 1,4-dioxane (4 mL), **10h** was isolated as colorless crystals (164 mg, 63%), mp. 140-142 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.73 (s, 3H, OCH_3), 3.81 (s, 3H, OCH_3), 3.84 (s, 3H, OCH_3), 3.85 (s, 3H, OCH_3), 6.71-6.75 (m, 2H, ArH), 6.89-7.06 (m, 7H, ArH), 7.14-7.20 (m, 2H, ArH), 7.32-7.44 (m, 2H, ArH), 7.70 (dd, *J* = 8.1, 1.3 Hz, 1H, ArH), 7.86 (s, 1H, ArH), 7.93 (dd, *J* = 8.0, 1.3 Hz, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 56.1 ($4OCH_3$), 111.1 (CH), 111.3 (CH), 113.4 (CH), 113.6 (CH), 121.4 (2CH), 122.5 (2CH), 125.8 (CH), 126.1 (CH), 126.3 (CH), 126.7 (CH), 127.7 (CH), 127.9 (C), 128.2 (CH), 129.4 (2CH), 131.3 (C), 132.6 (C), 133.3 (C), 133.5 (C), 140.2 (C), 140.3 (C), 148.7 (C), 148.8 (2C), 148.9 (C), 150.8 (C), 167.3 (C=O); IR (ATR, cm^{-1}):

$\tilde{\nu}$ = 3066 (w), 2931 (w), 2834 (w), 1732 (m), 1589 (w), 1510 (s), 1461 (m), 1372 (m), 1238 (s), 1220 (s), 1187 (s), 1095 (s), 1023 (s), 923 (w), 761 (m), 687 (m), 597 (w); MS (GC, 70 eV): *m/z* (%): 520 (M^+, 16), 428 (27), 427 (63), 410 (11), 396 (54), 239 (7), 183 (100), 170 (21), 147 (29), 120 (89), 107 (27); HRMS (EI) calcd for $C_{33}H_{28}O_6$ [M^+]: 520.18804 found 520.18900.

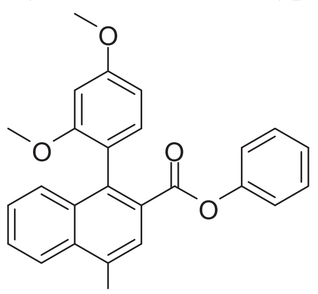
Phenyl 1-(2-ethoxyphenyl)-4-(trifluoromethylsulfonyloxy)-2-naphthoate (11a):



Chemical Formula: $C_{26}H_{19}F_3O_6S$
Exact Mass: 516.09

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (160 mg, 0.75 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9k** (91 mg, 0.55 mmol) and 1,4-dioxane (4 mL), **11a** was isolated as colorless crystals (152 mg, 59%), mp. 87-89 °C; ^1H NMR (300 MHz, $CDCl_3$): δ = 0.98 (t, *J* = 7.0 Hz, 3H, CH_3), 3.86 (q, *J* = 7.0 Hz, 2H, OCH_2), 6.76-6.80 (m, 2H, ArH), 6.94 (d, *J* = 8.0 Hz, 1H, ArH), 7.00 (dt, *J* = 7.4, 1.0 Hz, 1H, ArH), 7.06-7.38 (m, 5H, ArH), 7.46 (dt, *J* = 8.0, 1.2 Hz, 1H, ArH), 7.61 (d, *J* = 8.4 Hz, 1H, ArH), 7.66 (dt, *J* = 7.6, 1.2 Hz, 1H, ArH), 8.04 (s, 1H, ArH), 8.10 (d, *J* = 8.4 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 14.7 (CH_3), 64.1 (OCH_2), 112.3 (CH), 118.3 (CH), 119.0 (q, $^1J_{CF}$ = 321 Hz, CF_3), 120.6 (CH), 121.0 (CH), 121.4 (2CH), 126.0 (CH), 126.9 (C), 127.7 (C), 128.1 (CH), 128.3 (C), 128.7 (CH), 129.5 (2CH), 129.7 (CH), 129.9 (CH), 131.3 (CH), 134.6 (C), 140.3 (C), 145.0 (C), 150.8 (C), 156.6 (C), 165.2 (C=O); ^{19}F NMR (282.40 MHz, $CDCl_3$): δ = -73.16 (3F, CF_3); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3063 (w), 2926 (w), 2854 (w), 1744 (m), 1598 (w), 1491 (m), 1421 (m), 1332 (w), 1244 (m), 1201 (s), 1185 (s), 1127 (s), 1012 (s), 925 (m), 843 (m), 753 (s), 724 (s), 687 (m), 607 (s); MS (GC, 70 eV): *m/z* (%): 516 (M^+, 7), 424 (19), 423 (90), 396 (19), 395 (100), 263 (16), 262 (78), 261 (20), 234 (26), 233 (25), 205 (28), 176 (17), 65 (6); HRMS (EI) calcd for $C_{26}H_{19}O_6F_3S$, [M^+]: 516.08490 found 516.08473.

Phenyl 1-(2,4-dimethoxyphenyl)-4-(trifluoromethylsulfonyloxy)-2-naphthoate (11b):

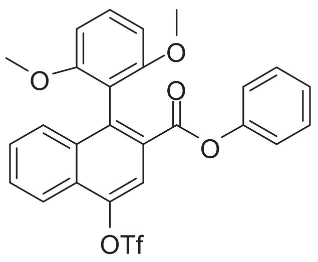


Chemical Formula: $C_{26}H_{19}F_3O_7S$
Exact Mass: 532.08

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (160 mg, 0.75 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9e** (100 mg, 0.55 mmol) and 1,4-dioxane (4 mL), **11b** was isolated as brownish semisolid (176 mg, 66%); ^1H NMR (300 MHz, $CDCl_3$): δ = 3.55 (s, 3H, OCH_3), 3.77 (s, 3H, OCH_3), 6.51-6.56 (m, 2H, ArH), 6.81-6.86 (m, 2H, ArH), 7.0 (d, *J* = 8.1 Hz, 1H, ArH), 7.06-

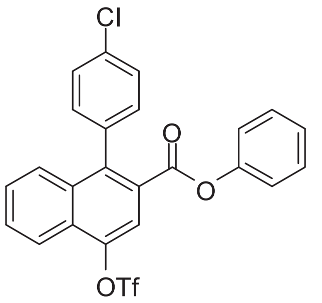
7.25 (m, 3H, ArH), 7.45 (dt, J = 7.7, 1.1 Hz, 1H, ArH), 7.61-7.66 (m, 2H, ArH), 8.02 (s, 1H, ArH), 8.07 (d, J = 7.8 Hz, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 55.6 (OCH_3), 55.8 (OCH_3), 99.0 (CH), 104.6 (CH), 118.2 (CH), 118.9 (C), 119.0 (q, $^{1}J_{CF}$ = 321 Hz, CF_3), 121.0 (CH), 121.5 (2CH), 126.1 (CH), 127.9 (C), 128.2 (CH), 128.3 (C), 128.7 (CH), 129.5 (2CH), 129.7 (CH), 131.5 (CH), 135.0 (C), 140.1 (C), 145.0 (C), 150.8 (C), 158.3 (C), 161.5 (C), 165.1 (C=O); ^{19}F NMR (282.40 MHz, $CDCl_3$): δ = -73.08 (3F, CF_3); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3072 (w), 2937 (w), 2837 (w), 1729 (m), 1591 (m), 1512 (m), 1417 (m), 1337 (m), 1203 (s), 1186 (s), 1132 (s), 1011 (s), 965 (m), 830 (s), 762 (s), 687 (m), 597 (s); MS (EI, 70 eV): *m/z* (%): 532 (M^+, 17), 440 (18), 439 (100), 307 (15), 306 (52), 275 (14), 263 (21), 220 (5) 176 (4), 94 (18), 69 (11), 45 (27), 44 (40), 43 (49); HRMS (EI) calcd for C_{26} H_{19} O_7 F_3 S, [M^+]: 532.07981 found 532.07979.

Phenyl 1-(2,6-dimethoxyphenyl)-4-(trifluoromethylsulfonyloxy)-2-naphthoate (11c):


Chemical Formula: $C_{26}H_{19}F_3O_7S$
Exact Mass: 532.08

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (160 mg, 0.75 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9i** (100 mg, 0.55 mmol) and 1,4-dioxane (4 mL), **11c** was isolated as colorless crystals (88 mg, 33%), mp. 162-164 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.53 (s, 6H, OCH_3), 6.62 (d, J = 8.4 Hz, 2H, Ar), 6.79-6.84(m, 2H, ArH), 7.06-7.12 (m, 1H, ArH), 7.20-7.26 (m, 2H, ArH), 7.33 (t, J = 8.26, 1H, ArH), 7.41-7.48 (m, 1H, ArH), 7.55 (d, J = 8.1 Hz, 1H, ArH), 7.64 (dt, J = 7.8, 1.3 Hz, 1H, ArH), 8.07 (d, J =8.3 Hz, 1H, ArH), 8.08 (s, 1H, ArH); ^{13}C NMR (62.90 MHz, $CDCl_3$): δ = 55.9 (2OCH_3), 104.1 (2CH), 114.8 (C), 118.3 (CH), 118.8 (q, $^{1}J_{CF}$ = 321 Hz, CF_3), 120.9 (CH), 121.3 (2CH), 125.7 (CH), 127.7 (C), 127.9 (CH), 128.0 (CH), 128.2 (C), 129.3 (2CH), 129.5 (CH), 129.9 (CH), 130.1 (CH), 134.3 (C), 137.0 (C), 144.9 (C), 150.7 (C), 157.8 (2C), 164.7 (C=O); ^{19}F NMR (282.4 MHz. $CDCl_3$): δ = -73.24 (3F, CF_3); IR $\widetilde{\nu}$ = IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3014 (w), 2937 (w), 2839 (w), 1723(m), 1589 (w), 1510 (w), 1470 (m), 1413 (m), 1336 (m), 1247 (m), 1192 (s), 1109 (s), 1011 (m), 956 (m), 828 (m), 747 (m), 687 (m), 599 (m); MS (EI, 70 eV): *m/z* (%): 532 (M^+, 4), 441 (7), 440 (21), 439 (100), 306 (17), 275 (25), 263 (20), 248 (4), 220 (6) 176 (2), 94 (3), 69 (4), 43 (5); HRMS (EI) calcd for C_{26} H_{19} O_7 F_3 S, [M^+]: 532.07981 found 532.080106.

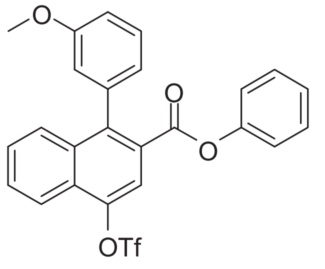
Phenyl 1-(4-chlorophenyl)-4-(trifluoromethylsulfonyloxy)-2-naphthoate (11d):



Chemical Formula: $C_{24}H_{14}ClF_3O_5S$
Exact Mass: 506.02

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (160 mg, 0.75 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9g** (86 mg, 0.55 mmol) and 1,4-dioxane (4 mL), **11d** was isolated as colorless crystals (185 mg, 73%), mp. 82-84 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.78-6.81 (m, 2H, ArH), 7.08-7.53 (m, 9H, ArH), 7.68 (dt, *J* = 8.6, 1.8 Hz, 1H, ArH), 8.03 (s, 1H, ArH), 8.11 (d, *J* = 8.5 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 118.1 (CH), 118.9 (q, $^1J_{CF}$ = 321 Hz, CF_3), 121.2 (CH), 121.3 (2CH), 126.3 (CH), 127.1 (C), 128.3 (C), 128.5 (CH), 128.7 (CH), 128.8 (2CH), 129.7 (2CH), 130.1 (CH), 131.1 (2CH), 134.5 (2C), 136.1 (C), 142.0 (C), 145.3 (C), 150.5 (C), 164.8 (C=O); ^{19}F NMR (282.40 MHz, $CDCl_3$): δ = -73.04 (3F, CF_3); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3074 (w), 1731 (m), 1591 (w), 1490 (m), 1420 (m), 1336 (m), 1240 (m), 1186 (s), 1135 (s), 1087 (m), 1011 (s), 964 (m), 825 (s), 762 (s), 686 (m), 597 (s). MS (GC, 70 eV): *m/z* (%): 506 (M^+, ^{35}Cl, 2), 415 (40), 414 (22), 413 (100), 245 (49), 217 (28), 189 (20), 65 (4), 39 (2). HRMS (EI) calcd for $C_{24}H_{14}O_5ClF_3S$, [M^+, ^{35}Cl]: 506.01971 found 506.02008.

Phenyl 1-(3-methoxyphenyl)-4-(trifluoromethylsulfonyloxy)-2-naphthoate (11e):

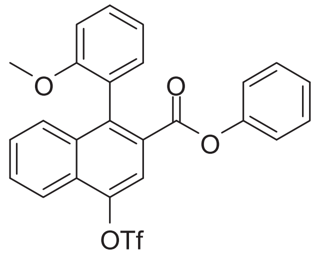


Chemical Formula: $C_{25}H_{17}F_3O_6S$
Exact Mass: 502.07

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (160 mg, 0.75 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9d** (84 mg, 0.55 mmol) and 1,4-dioxane (4 mL), **11e** was isolated as colorless semisolid (173 mg, 69%); ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.71 (s, 3H, OCH_3), 6.74-6.77 (m, 2H, ArH), 6.84-6.96 (m, 3H, ArH), 7.06-7.25 (m, 3H, ArH), 7.33 (t, *J* = 7.8 Hz, 1H, ArH), 7.48 (dt, *J* = 8.6, 1.1 Hz, 1H, ArH), 7.36-7.70 (m, 2H, ArH), 7.98 (s, 1H, ArH), 8.10 (d, *J* = 8.2 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 55.5 (OCH_3), 114.0 (CH), 115.5 (CH), 118.0 (CH), 119.0 (q, $^1J_{CF}$ = 321 Hz, CF_3), 121.0 (CH), 121.4 (2CH), 122.4 (CH), 126.2 (CH), 127.4 (C), 128.2 (C), 128.5 (CH), 128.8 (CH), 129.5 (3CH), 129.9 (CH), 134.5 (C), 139.0 (C), 142.7 (C), 145.1 (C), 150.6 (C), 159.7 (C), 165.3 (C=O); ^{19}F NMR (282.40 MHz, $CDCl_3$): δ = -73.08 (3F, CF_3); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3072 (w), 2939 (w), 2836 (w), 1729 (m), 1589 (m), 1509 (w), 1487 (m), 1419 (s), 1336 (m), 1243 (m), 1186 (s), 1134 (s), 1014 (s), 859 (m), 813 (s), 762 (s), 686 (s), 598 (s); MS (EI, 70 eV): *m/z* (%): 502 (M^+, 3), 410 (19), 409 (100), 408 (38), 276 (92), 275 (22), 205

(10), 176 (8), 119 (3), 94 (6), 69 (10), 43 (33); HRMS (EI) calcd for $C_{25} H_{17} O_6 F_3 S$, [M^+]: 502.06925 found 502.06944.

Phenyl 1-(2-methoxyphenyl)-4-(trifluoromethylsulfonyloxy)-2-naphthoate (11f):



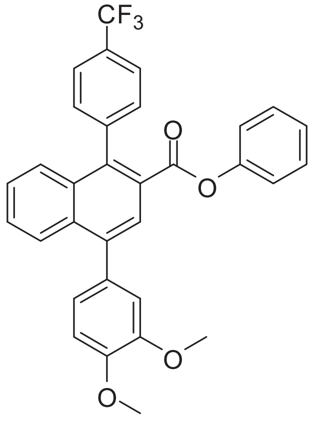
Chemical Formula: $C_{25}H_{17}F_3O_6S$
Exact Mass: 502.07

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (160 mg, 0.75 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9j** (84 mg, 0.55 mmol) and 1,4-dioxane (4 mL), **11f** was isolated as colorless crystals (156 mg, 62%), mp. 85-87 °C; ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.54 (s, 3H, OCH_3), 6.73-6.77 (m, 2H, ArH), 6.90-7.21 (m, 6H, ArH), 7.35 (dt, *J* = 8.0, 1.6 Hz, 1H, ArH), 7.44 (d, *J* = 7.6 Hz, 1H, ArH), 7.54 (s, 1H, ArH), 7.57-7.64 (m, 1H, ArH), 8.03 (s, 1H, ArH), 8.07 (d, *J* = 8.4 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 55.7 (OCH_3), 111.1 (CH), 118.3 (CH), 118.9 (q, $^1J_{CF}$ = 321 Hz, CF_3), 120.7 (CH), 121.1 (CH), 121.4 (2CH), 126.0 (CH), 126.6 (C), 127.6 (C), 128.2 (CH), 128.3 (C), 128.6 (CH), 129.5 (2CH), 129.8 (CH), 130.7 (CH), 131.0 (CH), 134.6 (C), 140.2 (C), 145.1 (C), 150.7 (C), 157.3 (C), 165.5 (C=O); ^{19}F NMR (282.40 MHz, $CDCl_3$): δ = -73.16 (3F, CF_3); IR (ATR, cm^{-1}) $\tilde{\nu}$ = 3072 (w), 2917 (w), 2848 (w), 1728(m), 1600 (w), 1492 (m), 1419 (m), 1337 (m), 1247 (m), 1186 (s), 1135 (s), 1121 (s), 1012 (s), 964 (m), 834 (s), 751 (s), 597 (s); MS (EI, 70 eV): *m/z* (%): 502 (M^+, 4), 410 (20), 409 (100), 345 (5), 276 (22), 261 (14), 233 (25), 205 (8), 189 (4), 176 (5), 94 (3), 65 (3); HRMS Pos (ESI) calcd for $C_{25}H_{18}F_3O_6S$ $[M+H]^+$calcd is 503.0771 found 503.0774 and exact ion mass is 502.0698.

General Procedure for synthesis of 12a-f:

The reaction was carried out in a pressure tube. To a dioxane suspension (4 mL) of **2** (272 mg, 0.5 mmol), $Pd(PPh_3)_4$ (3 mol%) and K_3PO_4 (159 mg, 0.75 mmol) was added $Ar^1B(OH)_2$ (0.55 mmol) and the solution was degassed by bubbling argon through the solution for 10 min. The reaction mixture was heated at 95 °C under argon atmosphere for 7 h. The reaction mixture was cooled to 20 °C and $Ar^2B(OH)_2$ (0.65 mmol) and K_3PO_4 (159 mg, 0.75 mmol) were added. The reaction mixture was heated under Argon atmosphere for 8h at 110 °C. They were diluted with water and extracted with CH_2Cl_2 (3 x 25 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated *in vacuo*. The residue was purified by flash chromatography (silica gel, EtOAc / heptanes).

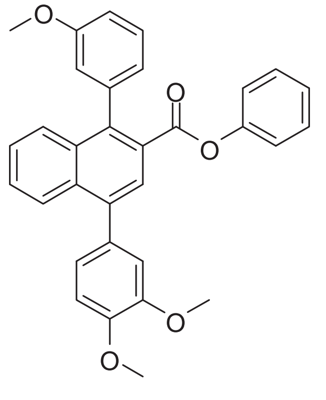
Phenyl 4-(3,4-dimethoxyphenyl)-1-(4-(trifluoromethyl)phenyl)-2-naphthoate (12a):



Chemical Formula: $C_{32}H_{23}F_3O_4$
Exact Mass: 528.15

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9b** (104 mg, 0.55 mmol), 1,4-dioxane (4 mL), and **9h** (118 mg, 0.65 mmol), **12a** was isolated as colourless crystals (134 mg, 51%), mp. 163-165 °C; ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.85 (s, 3H, OCH_3), 3.90 (s, 3H, OCH_3), 6.70-6.73(m, 2H, ArH), 6.96 (d, *J* = 8.2 Hz, 1H, ArH), 7.01-7.11 (m, 3H, ArH), 7.17-7.24 (m, 2H, ArH), 7.40 (dd, *J* = 7.3, 2.4 Hz, 1H, ArH), 7.44-7.50 (m, 4H, ArH), 7.68-7.71 (m, 2H, ArH), 7.95-7.99 (m, 1H, ArH), 8.0 (s, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 56.0 (OCH_3), 56.1 (OCH_3), 111.3 (CH), 113.3 (CH), 121.2 (2CH), 122.4 (CH), 124.3 (q, J_{CF} = 272 Hz, CF), 125.2 (q, J_{CF} = 3.8 Hz, 2CH), 125.9 (CH), 126.4 (CH), 126.5 (CH), 126.8 (C), 126.9 (CH), 127.8 (CH), 128.1 (CH), 129.4 (2CH), 129.9 (q, J_{CF} = 32.5 Hz, C), 130.3 (2CH), 132.3 (C), 132.8 (C), 133.7 (C), 139.7 (C), 140.9 (C), 143.1 (C), 148.9 (C), 149.0 (C), 150.5 (C), 166.2 (C=O); ^{19}F NMR (282.4 MHz. $CDCl_3$): δ = -62.38 (3F, $ArCF_3$). IR $\tilde{\nu}$ = IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3065 (w), 2966 (w), 2838 (w), 1712 (m), 1597 (w), 1515 (m), 1406 (w), 1320 (m), 1239 (m), 1212 (m), 1159 (s), 1101 (s), 1023 (m), 923 (w), 775 (m), 744 (m), 685 (m), 623 (m), 549 (w); MS (EI, 70 eV): *m/z* (%): 528 (M^+, 18), 436 (27), 435 (100), 376 (4), 333 (4), 252 (3), 207 (3), 153 (3), 94 (18), 69 (13), 60 (25), 43 (29); HRMS (EI) calcd for $C_{32}H_{23}O_4F_3[M^+]$: 528.15430 found 528.154433.

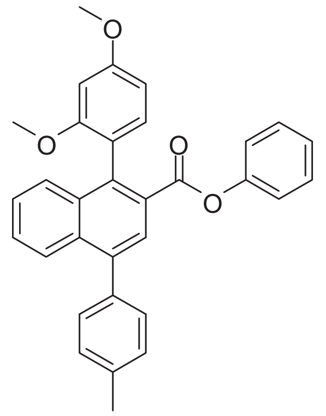
Phenyl 4-(3,4-dimethoxyphenyl)-1-(3-methoxyphenyl)-2-naphthoate (12b):



Chemical Formula: $C_{32}H_{26}O_5$
Exact Mass: 490.18

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9d** (84 mg, 0.55 mmol), 1,4-dioxane (4 mL), and **9h** (118 mg, 0.65 mmol), **12b** was isolated as colourless crystals (113 mg, 46%), mp. 143-145 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.72 (s, 3H, OCH_3), 3.83 (s, 3H, OCH_3), 3.89 (s, 3H, OCH_3), 6.70-6.74 (m, 2H, ArH), 6.92-7.08 (m, 7H, ArH), 7.16-7.22 (m, 2H, ArH), 7.31-7.39 (m, 2H, ArH), 7.44 (dt, *J* = 8.3, 1.5 Hz, 1H, ArH), 7.67 (d, *J* = 8.7 Hz, 1H, ArH), 7.90 (s, 1H, ArH), 7.94 (d, *J* = 8.1 Hz, 1H, ArH). ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 55.5 (OCH_3), 56.2 ($2OCH_3$), 111.4 (CH), 113.5 (2CH), 115.8 (CH), 121.5 (2CH), 122.6 (CH), 122.7 (CH), 125.9 (CH), 126.3 (CH), 126.4 (CH), 126.8 (CH), 127.5 (C), 127.9 (CH), 128.4 (CH), 129.3 (CH), 129.4 (2CH), 132.7 (C), 133.1 (C), 133.6 (C), 140.4 (2C), 140.6 (C), 148.9 (C), 149.0 (C), 150.9 (C), 159.6 (C), 167.2 (C=O); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3060 (w), 2948 (w), 2831 (w), 1737 (s), 1586 (m), 1514 (m), 1407 (w), 1316 (w), 1241 (m), 1220 (s), 1187 (s), 1135 (s), 1100 (s), 1022 (s), 935 (w), 812 (m), 766 (m), 686 (m), 595 (w); MS (EI, 70 eV): *m/z* (%): 490 (M$^+$, 14), 398 (28), 397 (100), 339 (3), 239 (3), 149 (3), 123 (5), 111 (4), 97 (7), 57 (13), 44 (19), 43 (27); HRMS (EI) calcd for $C_{32}H_{26}O_5$ [M$^+$]: 490.17748 found 490.17793.

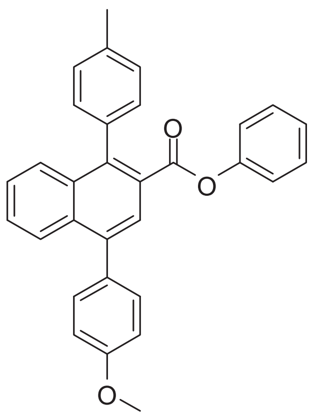
Phenyl 1-(2,4-dimethoxyphenyl)-4-p-tolyl-2-naphthoate (12c):



Chemical Formula: $C_{32}H_{26}O_4$
Exact Mass: 474.18

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9e** (100 mg, 0.55 mmol), 1,4-dioxane (4 mL), and **9c** (88 mg, 0.65 mmol), **12c** was isolated as brown semisolid (149 mg, 63%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.26 (s, 3H, $ArCH_3$), 3.58 (s, 3H, OCH_3), 3.76 (s, 3H, OCH_3), 6.53-6.56 (m, 2H, ArH), 6.79-6.82 (m, 2H, ArH), 7.02-7.08 (m, 2H, ArH), 7.17-7.40 (m, 7H, ArH), 7.62 (dd, *J* = 7.7, 1.3 Hz, 1H, ArH), 7.89 (d, *J* = 8.2 Hz, 1H, ArH), 7.94 (s, 1H, ArH), 8.0 (s, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 21.4 (CH_3), 55.6 (OCH_3), 55.9 (OCH_3), 99.1 (CH), 104.5 (CH), 120.5 (C), 121.7 (2CH), 125.7 (CH), 126.4 (CH), 126.5 (CH), 126.8 (CH), 127.7 (CH), 127.9 (C), 128.3 (CH), 129.3 (2CH), 129.4 (2CH), 130.2 (2CH), 131.7 (CH), 133.6 (C), 133.7 (C), 137.3 (C), 137.5 (C), 138.0 (C), 140.1 (C), 151.1 (C), 158.5 (C), 161.0 (C), 166.9 (C=O); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3065 (w), 2933 (w), 2834 (w), 1731 (m), 1591 (w), 1508 (m), 1414 (w), 1302 (m), 1234 (m), 1205 (s), 1186 (s), 1156 (s), 1091 (s), 1030 (s), 981 (m), 823 (m), 763 (s), 686 (m), 596 (m); MS (EI, 70 eV): *m/z* (%): 474 (M$^+$, 9), 382 (25), 381 (100), 323 (7), 183 (2), 149 (3), 97 (4), 69 (7), 57 (7), 44 (16), 43 (23); HRMS (EI) calcd for $C_{32}H_{26}O_4$ [M$^+$]: 474.18256 found 474.18229.

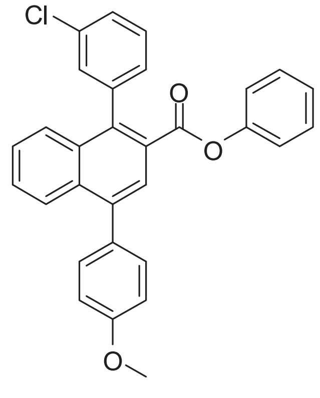
Phenyl 4-(4-methoxyphenyl)-1-p-tolyl-2-naphthoate (12d):



Chemical Formula: $C_{31}H_{24}O_3$
Exact Mass: 444.17

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9c** (75 mg, 0.55 mmol), 1,4-dioxane (4 mL), and **9n** (99 mg, 0.65 mmol), **12d** was isolated as colourless crystals (145 mg, 65%), mp. 112-114 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.35 (s, 3H, CH_3), 3.77 (s, 3H, OCH_3), 6.69-6.72 (m, 2H, ArH), 6.92 -7.05 (m, 3H, ArH), 7.14-7.40 (m, 10H, ArH), 7.63 (dd, *J* = 8.1, 0.8 Hz, 1H, ArH), 7.87 (s, 1H, ArH), 7.90 (d, *J* = 8.3 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 21.5 (CH_3), 55.5 (OCH_3), 114.1 (2CH), 121.6 (2CH), 125.8 (CH), 126.3 (CH), 126.4 (CH), 126.6 (CH), 127.7 (C), 127.8 (CH), 128.4 (CH), 129.0 (2CH), 129.4 (2CH), 130.0 (2CH), 131.4 (2CH), 132.4 (C), 133.4 (C), 133.6 (C), 136.0 (C), 137.3 (C), 140.0 (C), 141.0 (C), 150.9 (C), 159.5 (C), 167.2 (C=O); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3039 (w), 2929 (w), 2835 (w), 1741 (m), 1593 (w), 1510 (m), 1414 (w), 1302 (w), 1245 (m), 1198 (s), 1181 (s), 1161 (s), 1097 (s), 1032 (m), 982 (m), 832 (m), 749 (s), 686 (m), 594 (m); MS (EI, 70 eV): *m/z* (%): 444 (M^+, 14), 352 (39), 351 (100), 308 (8), 263 (6), 215 (4), 144 (4), 111 (4), 97 (6), 69 (9), 57 (10), 44 (10), 43 (18); HRMS (EI) calcd for $C_{31}H_{24}O_3$ [M^+]: 444.17200 found 444.17190.

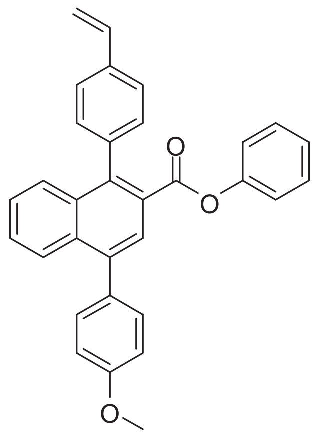
Phenyl 1-(3-chlorophenyl)-4-(4-methoxyphenyl)-2-naphthoate (12e):



Chemical Formula: $C_{30}H_{21}ClO_3$
Exact Mass: 464.12

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9l** (86 mg, 0.55 mmol), 1,4-dioxane (4 mL), and **9n** (99 mg, 0.65 mmol), **12e** was isolated as colourless semisolid (142 mg, 61%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.77 (s, 3H, OCH_3), 6.75-6.78 (m, 2H, ArH), 6.95 (td, *J* = 8.7, 2.1 Hz, 1H, ArH), 7.02-7.43 (m, 11H, ArH), 7.53 (dd, *J* = 8.4, 0.9 Hz, 1H, ArH), 7.92 (d, *J* = 8.1 Hz, 1H, ArH), 7.93 (brs, 2H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 55.6 (OCH_3), 114.1 (2CH), 121.5 (2CH), 126.0 (CH), 126.5 (CH), 126.6 (CH), 127.0 (CH), 127.2 (C), 127.9 (CH), 128.0 (CH), 128.1 (CH), 128.4 (CH), 129.5 (2CH), 129.6 (CH), 130.1 (CH), 131.3 (2CH), 132.2 (C), 133.0 (C), 133.7 (C), 134.3 (C), 139.5 (C), 140.7 (C), 141.1 (C), 150.8 (C), 159.6 (C), 166.6 (C=O); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3040 (w), 2929 (w), 2835 (w), 1731 (m), 1591 (w), 1504 (m), 1417 (w), 1377 (m), 1242 (s), 1210 (m), 1186 (s), 1160 (s), 1102 (s), 1031 (m), 992 (m), 833 (m), 764 (s), 686 (m), 582 (w); MS (GC, 70 eV): *m/z* (%): 464 (M^+, ^{35}Cl, 7), 372 (26), 371 (100), 336 (32), 308 (15), 276 (4), 263 (18), 237 (3), 132 (9), 65 (4); HRMS (EI) calcd for $C_{30}H_{21}O_3Cl$ [M^+, ^{35}Cl]: 464.11737 found 464.11658.

Phenyl 4-(4-methoxyphenyl)-1-(4-vinylphenyl)-2-naphthoate (12f):



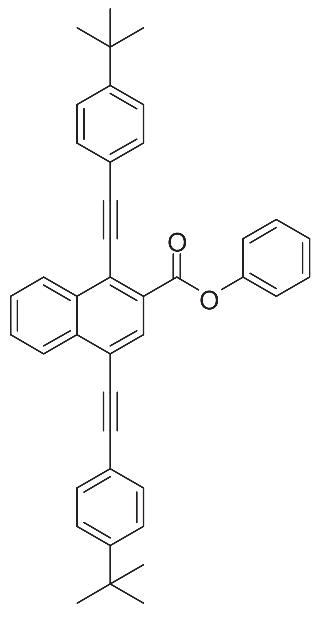
Chemical Formula: $C_{32}H_{24}O_3$
Exact Mass: 456.17

Starting with **8** (272 mg, 0.5 mmol), K_3PO_4 (318 mg, 1.5 mmol), $Pd(PPh_3)_4$ (3 mol-%), **9m** (81 mg, 0.55 mmol), 1,4-dioxane (4 mL), and **9n** (99 mg, 0.65 mmol), **12f** was isolated as colourless crystals (153 mg, 67%), mp. 103-105 °C; ^1H NMR (300 MHz, $CDCl_3$): δ = 3.77 (s, 3H, OCH_3), 5.20 (d, J = 11.0 Hz, 1H, vinyl), 5.72 (d, J = 17.5 Hz, 1H, vinyl), 6.66-6.75 (m, 3H, 2ArH +1 vinyl H), 6.93-7.04 (m, 3H, ArH), 7.13-7.45 (m, 10H, ArH), 7.61 (d, J = 7.9 Hz, 1H, ArH), 7.90 (s, 1H, ArH), 7.91 (dd, J = 7.7 Hz, 1H, ArH). ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 55.5 (OCH_3), 114.1 (2CH), 114.3 (CH_2), 121.6 (2CH), 125.9 (CH), 126.2 (2CH), 126.4 (CH), 126.5 (CH), 126.7 (CH), 127.5 (C), 127.9 (CH), 128.3 (CH), 129.4 (2CH), 130.4 (2CH), 131.3 (2CH), 132.3 (C), 133.2 (C), 133.7 (C), 136.7 (CH), 137.1 (C), 138.7 (C), 140.2 (C), 140.7 (C), 150.9 (C), 159.5 (C), 167.1 (C=O); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3065 (w), 2930 (w), 2834 (w), 1732 (m), 1606 (m), 1591 (w), 1509 (m), 1416 (w), 1303 (w), 1241 (s), 1186 (s), 1160 (s), 1095 (s), 1030 (m), 982 (m), 831 (s), 764 (s), 686 (m), 595 (m); MS (GC, 70 eV): *m/z* (%): 456 (M^+, 7), 364 (28), 363 (100), 321 (7), 289 (8), 263 (7), 207 (27), 181 (3), 94 (5), 32 (20); HRMS (EI) calcd for $C_{32}H_{24}O_3$ [M^+]: 456.17200 found 456.17161.

General Procedure for synthesis of 14a-f and 15a,b:

The reaction was carried out in a pressure tube under argon atmosphere. To a DMF suspension of **8** (272 mg, 0.5 mmol), $Pd(PPh_3)_4$, Bu_4NI, after stirring for 10 min was added dry CuI. Again after 10 min stirring triethylamine, was added followed by slow drop wise addition of alkyne. The reaction mixture was stirred at temperature of 80 or 60°C for 4 h for products **14** or **15** respectively under argon atmosphere. After cooling to 20 °C, then distilled water was added to the reaction mixture and extracted with CH_2Cl_2 (3 × 20 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in vacuo. The residue was purifed by chromatography (silica gel, heptanes / EtOAc).

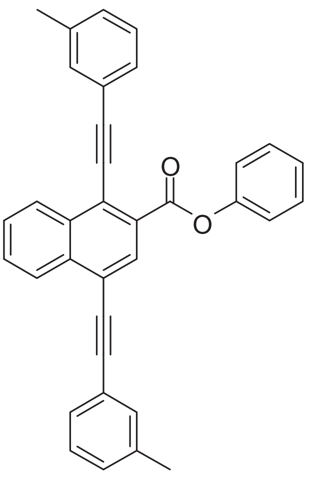
Phenyl 1,4-bis((4-tert-butylphenyl)ethynyl)-2-naphthoate (14a):



Chemical Formula: $C_{41}H_{36}O_2$
Exact Mass: 560.27

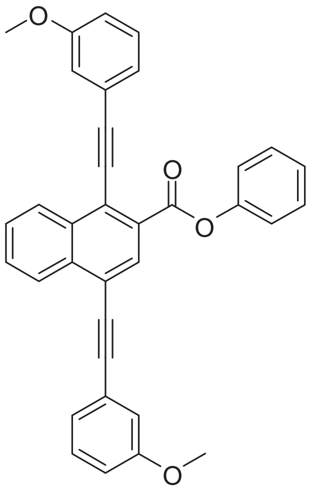
Starting with **8** (272 mg, 0.50 mmol), Pd $(PPh_3)_4$ (10 mol%), dry CuI (20 mol%), triethylamine (126 mg, 1.25 mmol), Bu_4NI (553 mg, 1.5mmol), **13a** (190 mg, 1.2 mmol) was added in DMF (5mL per 1 mmol of **8**), **14a** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as light green crystals (202 mg, 72%), mp. 212-213 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.27 (s, 9H, $3CH_3$), 1.30 (s, 9H, $3CH_3$), 7.24-7.41 (m, 9H, ArH), 7.49-7.56 (m, 4H, ArH), 7.65-7.70 (m, 2H, ArH), 8.38 (s, 1H, ArH), 8.45 (dd, J = 7.2, 2.1 Hz, 1H, ArH), 8.68 (dd, J = 7.2, 2.1 Hz, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 31.3 ($3CH_3$), 31.4 ($3CH_3$), 35.1 (2C), 85.8 (C), 86.5 (C), 97.0 (C), 103.7 (C), 120.1 (C), 120.3 (C), 121.7 (C), 122.0 (2CH), 123.6 (C), 125.7 (2CH), 125.8 (2CH), 126.1 (CH), 126.9 (CH), 128.2 (CH), 128.4 (CH), 129.2 (C), 129.3 (CH), 129.8 (2CH), 130.6 (CH), 131.7 (2CH), 131.9 (2CH), 133.7 (C), 134.6 (C), 151.3 (C), 152.4 (C), 152.6 (C), 165.0 (C=O); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 2959 (w), 2864 (w), 2208 (w), 1746 (m), 1591 (w), 1493 (m), 1390 (w), 1215 (m), 1196 (s), 1189 (s), 1129 (s), 1044 (m), 903 (m), 831 (s), 769 (m), 746 (m), 685 (m), 559 (s); MS (EI, 70 eV): *m/z* (%): 560 (M$^+$, 14), 468 (35), 467 (100), 352 (2), 226 (9), 207 (4), 123 (2), 94 (12), 66 (17), 44 (48), 43 (16); HRMS (EI) calcd for $C_{41}H_{36}O_2$ [M$^+$]: 560.27098 found 560.27228.

Phenyl 1,4-bis(m-tolylethynyl)-2-naphthoate (14b):


Chemical Formula: $C_{35}H_{24}O_2$
Exact Mass: 476.18

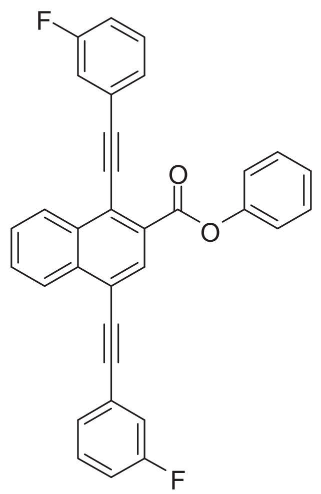
Starting with **8** (272 mg, 0.50 mmol), Pd $(PPh_3)_4$ (10 mol%), dry CuI (20 mol%), triethylamine (126 mg, 1.25 mmol), Bu_4NI (553 mg, 1.5mmol), **13b** (140 mg, 1.2 mmol) was added in DMF (5mL per 1 mmol of **8**), **14b** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as yellow crystals (183 mg, 77%), mp. 159-160 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.24 (s, 3H, CH_3), 2.30 (s, 3H, CH_3), 7.09-7.27 (m, 7H, ArH), 7.35-7.40 (m, 6H, ArH), 7.62-7.68 (m, 2H, ArH), 8.36 (s, 1H, ArH), 8.42 (dd, *J* = 7.2, 2.1 Hz, 1H, ArH), 8.64 (dd, *J* = 7.2, 2.1 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 21.4 (CH_3), 21.5 (CH_3), 86.0 (C), 86.7 (C), 97.0 (C), 103.7 (C), 121.6 (C), 122.0 (2CH), 122.9 (C), 123.0 (C), 123.6 (C), 126.2 (CH), 126.8 (CH), 128.2 (CH), 128.4 (CH), 128.5 (CH), 128.6 (CH), 129.1 (CH), 129.2 (C), 129.3 (CH), 129.4 (CH), 129.8 (2CH), 129.9 (CH), 130.1 (CH), 130.6 (CH), 132.5 (CH), 132.7 (CH), 133.6 (C), 134.6 (C), 138.3 (C), 138.4 (C), 151.2 (C), 164.8 (C=O); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3062 (w), 2952 (w), 2856 (w), 2199 (w), 1738 (m), 1591 (w), 1484 (m), 1371 (w), 1214 (m), 1187 (s), 1163 (m), 1125 (s), 1047 (m), 898 (m), 837 (w), 773 (s), 757 (s), 687 (s), 553 (m); MS (EI, 70 eV): *m/z* (%): 476 (M^+, 13), 384 (30), 383 (100), 355 (14), 340 (12), 339 (16), 337 (11), 263 (2), 169 (5), 119 (2), 94 (7), 44 (6), 40 (7); HRMS (EI) calcd for $C_{35}H_{24}O_2$ [M^+]: 476.17708 found 476.17798.

Phenyl 1,4-bis((3-methoxyphenyl)ethynyl)-2-naphthoate (14c):


Chemical Formula: $C_{35}H_{24}O_4$
Exact Mass: 508.17

Starting with **8** (272 mg, 0.50 mmol), Pd $(PPh_3)_4$ (10 mol%), dry CuI (20 mol%), triethylamine (126 mg, 1.25 mmol), Bu_4NI (553 mg, 1.5mmol), **13c** (158 mg, 1.2 mmol) was added in DMF (5mL per 1 mmol of **8**), **14c** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as greenish yellow solid (173 mg, 68%), mp. 129-130 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.59 (s, 3H, OCH_3), 3.71 (s, 3H, OCH_3), 6.77-6.83 (m, 2H, ArH), 6.98 (d, *J* = 2.2 Hz, 1H, ArH), 7.06-7.24 (m, 8H, ArH), 7.30-7.35 (m, 2H, ArH), 7.57-7.62 (m, 2H, ArH), 8.31 (s, 1H, ArH), 8.35 (dd, *J* = 7.2, 2.2 Hz, 1H, ArH), 8.58 (dd, J = 7.2, 2.2 Hz, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 55.4 (OCH_3), 55.5 (OCH_3), 86.1 (C), 86.8 (C), 96.7 (C), 103.4 (C), 115.6 (CH), 116.0 (CH), 116.5 (CH), 116.7 (CH), 121.5 (C), 122.0 (2CH), 123.4 (C), 124.0 (C), 124.1 (C), 124.5 (CH), 124.7 (CH), 126.1 (CH), 126.7 (CH), 128.2 (CH), 128.3 (CH), 129.1 (C), 129.4 (CH), 129.6 (CH), 129.7 (3CH), 130.7 (CH), 133.5 (C), 134.4 (C), 151.2 (C), 159.5 (C), 159.6 (C), 164.7 (C=O); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3061 (w), 2921 (w), 2851 (w), 2201 (w), 1736 (s), 1593 (m), 1486 (m), 1368 (w), 1282 (w), 1227 (s), 1192 (s), 1155 (s), 1125 (s), 1044 (s), 930 (w), 841 (m), 758 (s), 738 (s), 679 (s), 619 (m), 549 (w); MS (EI, 70 eV): *m/z* (%): 508 (M^+, 19), 417 (10), 416 (32), 415 (100), 387 (8), 313 (6), 300 (7), 208 (2), 150 (4), 94 (3), 44 (6); HRMS (EI) calcd for $C_{35}H_{24}O_4$ [M^+]: 508.16691 found 508.16567.

Phenyl 1,4-bis((3-fluorophenyl)ethynyl)-2-naphthoate (14d):

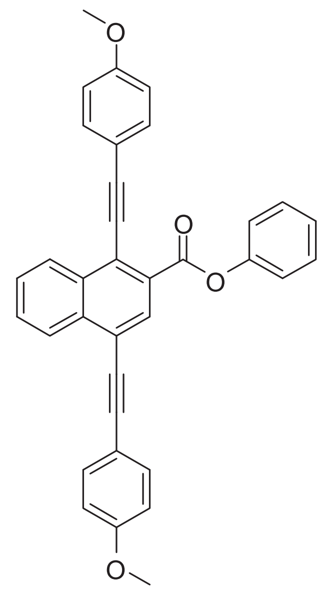


Chemical Formula: $C_{33}H_{18}F_2O_2$
Exact Mass: 484.13

Starting with **8** (272 mg, 0.50 mmol), Pd (PPh_3)$_4$ (10 mol%), dry CuI (20 mol%), triethylamine (126 mg, 1.25 mmol), Bu_4NI (553 mg, 1.5mmol), **13d** (144 mg, 1.2 mmol) was added in DMF (5mL per 1 mmol of **8**), **14d** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as yellow solid (150 mg, 62%), mp. 167-168 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.96-7.06 (m, 2H, ArH), 7.20-7.42 (m, 11H, ArH), 7.66-7.70 (m, 2H, ArH), 8.39 (s, 1H, ArH), 8.40 (dd, J = 7.2, 2.1 Hz, 1H, ArH), 8.61 (dd, J = 7.2, 2.1 Hz, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 86.9 (C), 87.8 (C), 95.5 (d, J_{CF} = 3.3 Hz, C), 102.1 (d, J_{CF} = 3.3 Hz, C), 116.5 (d, J_{CF} = 21.3 Hz, CH), 116.6 (d, J_{CF} = 21.3 Hz, CH), 118.7 (d, J_{CF} = 22.8 Hz, CH), 118.8 (d, J_{CF} = 22.8 Hz, CH), 121.5 (C), 121.9 (2CH), 123.5 (C), 124.8 (d, J_{CF} = 9.6 Hz, C), 125.0 (d, J_{CF} = 9.6 Hz, C), 126.3 (CH), 126.7 (CH), 127.9 (d, J_{CF} = 3.1 Hz, CH), 128.1 (d, J_{CF} = 3.1 Hz, CH), 128.3 (CH), 128.5 (CH), 129.4 (C), 129.7 (CH), 129.8 (2CH), 130.3 (d, J_{CF} = 8.6 Hz, CH), 130.4 (d, J_{CF} = 8.6 Hz, CH), 130.9 (CH), 133.6 (C), 134.5 (C), 151.2 (C), 162.6 (d, $^1J_{CF}$ = 247 Hz, CF), 162.7 (d, $^1J_{CF}$ = 247 Hz, CF), 164.6 (C=O); ^{19}F NMR (282.40 MHz, $CDCl_3$): δ = -112.47 (ArF), -112.59 (ArF); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3067 (w), 2188 (w), 1715 (s), 1602 (m), 1571 (m), 1484 (m), 1370 (w), 1280 (w), 1231 (m), 1195 (m), 1186 (s), 1120 (m), 1038 (w), 927 (w), 874 (m), 761 (s), 736 (s), 682 (s), 619 (w), 527 (w); MS (EI, 70 eV): *m/z* (%): 484 (M^+, 11), 393 (23), 392 (31), 391 (100), 364 (15), 363 (33), 362 (52), 360 (22), 342 (14), 181

(14), 98 (6), 94 (34), 83 (10), 69 (23), 43 (25); HRMS (EI) calcd for C_{33} H_{18} O_2 F_2 [M^+]: 484.12694 found 484.12766.

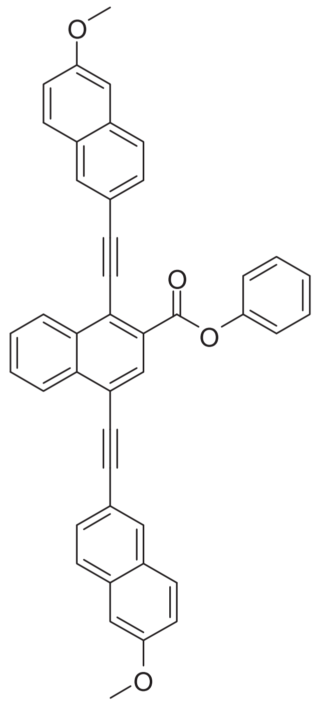
Phenyl 1,4-bis((4-methoxyphenyl)ethynyl)-2-naphthoate (14e):



Chemical Formula: $C_{35}H_{24}O_4$
Exact Mass: 508.17

Starting with **8** (272 mg, 0.50 mmol), Pd $(PPh_3)_4$ (10 mol%), dry CuI (20 mol%), triethylamine (126 mg, 1.25 mmol), Bu_4NI (553 mg, 1.5mmol), **13e** (158 mg, 1.2 mmol) was added in DMF (5mL per 1 mmol of **8**), **14e** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as greenish yellow solid (160 mg, 63%), mp. 158-159 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.73 (s, 3H, OCH_3), 3.75 (s, 3H, OCH_3), 6.79 (td, J = 8.7, 2.6 Hz, 2H, ArH), 6.84 (td, J = 8.8, 2.8 Hz, 2H, ArH), 7.21-7.26 (m, 3H, ArH), 7.35-7.40 (m, 2H, ArH), 7.46-7.53 (m, 4H, ArH), 7.61-7.65 (m, 2H, ArH), 8.33 (s, 1H, ArH), 8.40 (dd, J = 7.2, 2.2 Hz, 1H, ArH), 8.63 (dd, J = 7.2, 2.2 Hz, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 55.5 ($2OCH_3$), 85.4 (C), 86.0 (C), 96.8 (C), 103.8 (C), 114.3 (2CH), 114.4 (2CH), 115.2 (C), 115.4 (C), 121.5 (C), 122.0 (2CH), 123.7 (C), 126.1 (CH), 126.8 (CH), 128.1 (CH), 128.4 (CH), 128.8 (C), 129.2 (CH), 129.7 (2CH), 130.4 (CH), 133.5 (2CH), 133.6(C), 133.7 (2CH), 134.5 (C), 151.3 (C), 160.2 (C), 160.5 (C), 164.9 (C=O); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3060 (w), 2932 (w), 2838 (w), 2196 (w), 1744 (w), 1722 (w), 1602 (m), 1508 (s), 1450 (m), 1369 (w), 1288 (m), 1249 (s), 1190 (s), 1169 (s), 1128 (s), 1022 (s), 901 (m), 831 (s), 751 (s), 732 (m), 689 (m), 619 (m), 534 (m); MS (EI, 70 eV): *m/z* (%): 508 (M^+, 17), 417 (10), 416 (27), 415 (100), 387 (22), 301 (10), 300 (20), 194 (5), 172 (7), 150 (23), 137 (8), 94 (23), 66 (6), 55 (7), 43 (3); HRMS (EI) calcd for C_{35} H_{24} O_4 [M^+]: 508.16691 found 508.16707.

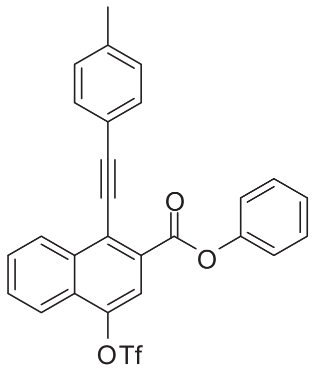
Phenyl 1,4-bis((6-methoxynaphthalen-2-yl)ethynyl)-2-naphthoate (14f):



Chemical Formula: $C_{43}H_{28}O_4$
Exact Mass: 608.20

Starting with **8** (272 mg, 0.50 mmol), Pd $(PPh_3)_4$ (10 mol%), dry CuI (20 mol%), triethylamine (126 mg, 1.25 mmol), Bu_4NI (553 mg, 1.5mmol), **13f** (218 mg, 1.2 mmol) was added in DMF (5mL per 1 mmol of **8**), **14f** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as yellow solid (158 mg, 52%), mp. 207-208 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.08 (s, 3H, OCH_3), 3.10 (s, 3H, OCH_3), 6.26-6.37 (m, 4H, ArH), 6.47-6.57 (m, 3H, ArH), 6.63-6.68 (m, 2H, ArH), 6.79-6.97 (m, 8H, ArH), 7.21 (brs, 1H, ArH), 7.27 (brs, 1H, ArH), 7.64 (s, 1H, ArH), 7.73 (dd, *J* = 6.9, 2.0 Hz, 1H, ArH), 7.96 (dd, *J* = 7.0, 2.0 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 55.5 ($2OCH_3$), 86.3 (C), 86.9 (C), 97.5 (C), 104.4 (C), 106.1 (2CH), 117.9 (C), 118.1 (C), 119.6 (CH), 119.7 (CH), 121.6 (C), 122.0 (2CH), 123.7 (C), 126.2 (CH), 126.9 (CH), 127.1 (CH), 127.2 (CH), 128.2 (CH), 128.4 (CH), 128.6 (C), 128.7 (C), 129.0 (C), 129.1 (CH), 129.2 (CH), 129.3 (CH), 129.6 (CH), 129.7 (CH), 129.8 (2CH), 130.6 (CH), 131.8 (CH), 132.2 (CH),133.6 (C), 134.5 (C), 134.6 (C), 134.8 (C), 151.3 (C), 158.7 (C), 158.8 (C), 164.8 (C=O); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3057 (w), 2932 (w), 2842 (w), 2199 (w), 1744 (m), 1622 (w), 1593 (m), 1484 (m), 1393 (m), 1328 (w), 1248 (m), 1198 (s), 1160 (s), 1127 (s), 1024 (s), 934 (m), 892 (s), 853 (s), 753 (s), 685 (m), 617 (w), 534 (m); MS (EI, 70 eV): *m/z* (%): 608 (M^+, 6), 516 (9), 515 (24), 400 (6), 207 (11), 169 (9), 130 (40), 119 (4), 94 (20), 60 (11), 57 (12), 55 (12), 45 (15), 44 (100), 43 (27); HRMS (EI) calcd for $C_{43}H_{28}O_4$ [M^+]: 608.19821 found 608.19894.

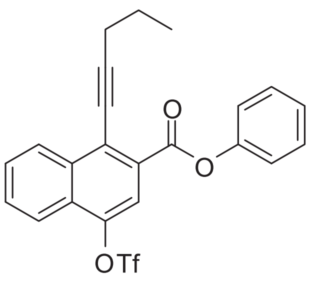
Phenyl 1-(p-tolylethynyl)-4-(trifluoromethylsulfonyloxy)-2-naphthoate (15a):



Chemical Formula: $C_{27}H_{17}F_3O_5S$
Exact Mass: 510.07

Starting with **8** (272 mg, 0.50 mmol), Pd $(PPh_3)_4$ (5 mol%), dry CuI (10 mol%), triethylamine (63 mg, 0.62 mmol), Bu_4NI (276 mg, 0.75mmol), **13g** (64 mg, 0.55 mmol) was added in DMF (5mL per 1 mmol of **8**), **15a** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as yellow solid (184 mg, 72%), mp. 105-107 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.31 (s, 3H, CH_3), 7.09-7.46 (m, 9H, ArH), 7.73-7.76 (m, 2H, ArH), 8.08 (d, *J* = 7.1 Hz, 1H, ArH), 8.10 (s, 1H, ArH), 8.71 (dd, *J* = 7.0, 2.2 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, CDCl$_3$): δ = 21.8 (CH$_3$), 84.6 (C), 104.4 (C), 118.7 (CH), 118.9 (q, $^1J_{CF}$ = 321 Hz, CF$_3$), 119.7 (C), 121.4 (CH), 121.9 (2CH), 124.9 (C), 126.4 (CH), 128.2 (C), 128.7 (CH), 128.9 (C), 129.2 (CH), 129.5 (2CH), 129.8 (2CH), 130.6 (CH), 132.2 (2CH), 135.2 (C), 140.0 (C), 144.7 (C), 151.0 (C), 163.8 (C=O); ^{19}F NMR (282.4 MHz. CDCl$_3$): δ = -73.03 (3F, CF$_3$); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3065 (w), 2961 (w), 2866 (w), 2204 (w), 1745 (m), 1592 (w), 1419 (m), 1336 (m), 1243 (m), 1188 (s), 1131 (s), 1070 (w), 1011 (s), 930 (w), 860 (s), 814 (s), 758 (s), 685 (s), 596 (s); MS (EI, 70 eV): *m/z* (%): 510 (M$^+$, 25), 419 (13), 418 (40), 417 (100), 369 (36), 284 (67), 256 (43), 226 (25), 213 (10), 112 (7), 97 (8), 94 (10), 83 (11), 71 (13), 57 (19), 43 (18); HRMS (EI) calcd for $C_{27}H_{17}O_5F_3S$, [M$^+$]: 510.07433 found 510.07408.

Phenyl 1-(pent-1-ynyl)-4-(trifluoromethylsulfonyloxy)-2-naphthoate (15b):



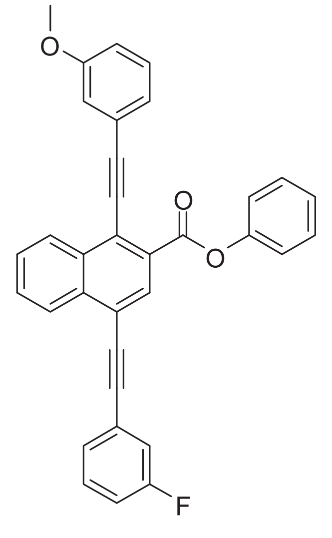
Chemical Formula: $C_{23}H_{17}F_3O_5S$
Exact Mass: 462.07

Starting with **8** (272 mg, 0.50 mmol), Pd (PPh$_3$)$_4$ (5 mol%), dry CuI (10 mol%), triethylamine (63 mg, 0.62 mmol), Bu$_4$NI (276 mg, 0.75mmol), **13h** (38mg, 0.55 mmol) was added in DMF (5mL per 1 mmol of **8**), **15b** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as light yellow solid (157 mg, 68%), mp. 78-79 °C; ^{1}H NMR (300 MHz, CDCl$_3$): δ = 1.01 (t, *J* = 7.4 Hz, 3H, CH$_3$), 1.65 (sextet, *J* = 7.2 Hz, 2H, CH$_2$), 2.55 (t, *J* = 7.0 Hz, 2H, CH$_2$), 7.20-7.25 (m, 3H, ArH), 7.37-7.42 (m, 2H, ArH), 7.67-7.75 (m, 2H, ArH), 8.03 (s, 1H, ArH), 8.06 (dd, *J* = 7.0, 1.7 Hz, 1H, ArH), 8.61 (dd, *J* = 7.1, 1.7 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, CDCl$_3$): δ = 14.0 (CH$_3$), 22.3 (CH$_2$), 22.4 (CH$_2$), 76.4 (C), 106.4 (C), 118.5 (CH), 119.0 (q, $^1J_{CF}$ = 321 Hz, CF$_3$), 121.3 (CH), 121.8 (2CH), 125.5 (C), 126.3 (CH), 128.2 (C), 128.8 (CH), 129.0 (CH), 129.1 (C), 129.8 (2CH), 130.4 (CH), 135.6 (C), 144.3 (C), 151.0 (C), 164.0 (C=O); ^{19}F NMR (282.4 MHz. CDCl$_3$): δ = -73.08 (3F, CF$_3$); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3073 (w), 2960 (w), 2871 (w), 2219 (w), 1746 (m), 1621 (w), 1591 (w), 1485 (w), 1420 (m), 1327 (m), 1245 (m), 1187 (s), 1136 (s), 1084 (m), 1011 (s), 920 (m), 827 (s), 760 (s), 688 (m), 596 (s). MS (EI, 70 eV): *m/z* (%): 462 (M$^+$, 10), 371 (20), 370 (64), 369 (100), 287 (26), 236 (72), 208 (82), 179 (17), 165 (33), 151 (14), 94 (16), 69 (11); HRMS (EI) calcd for $C_{23}H_{17}O_5F_3S$, [M$^+$]: 462.07433 found 462.07401.

General Procedure for synthesis of 16a,b:

The reaction was carried out in a pressure tube under argon atmosphere. To a DMF suspension of **8** (272 mg, 0.5 mmol), $Pd(PPh_3)_4$ (10mol%), Bu_4NI (300 mol%), after stirring for 10 min was added dry CuI (20 mol%). Again after 10 min stirring triethylamine (1.25 eq.) was added followed by slow dropwise addition of Ar^1-alkyne(0.55 mmol). The reaction mixture was stirred at temperature of 60°C for 3 h under argon atmosphere. The reaction mixture was cooled to 20 °C and triethylamine (1.25 eq.) was added again followed by slow dropwise addition of Ar^2alkyne (0.65 mmol). The reaction mixture was heated under Argon atmosphere for 4 h at 80 °C. After cooling to 20 °C, then distilled water was added to the reaction mixture and extracted with CH_2Cl_2 (3 × 20 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in vacuo. The residue was purifed by chromatography (silica gel, heptanes / EtOAc).

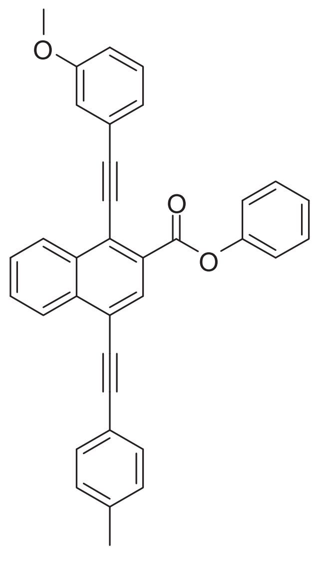
Phenyl 4-((3-fluorophenyl)ethynyl)-1-((3-methoxyphenyl)ethynyl)-2-naphthoate (16a):



Chemical Formula: $C_{34}H_{21}FO_3$
Exact Mass: 496.15

Starting with **8** (272 mg, 0.50 mmol), Pd $(PPh_3)_4$ (10 mol%), dry CuI (20 mol%), triethylamine (126 mg, 1.25 mmol), Bu_4NI (553 mg, 1.5mmol), **13c** (73 mg, 0.55 mmol) was added in DMF (5mL per 1 mmol of **8**), and **13d** (78 mg, 0.65 mmol), **16a** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as greenish yellow solid (134 mg, 54%), mp. 152-153 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.65 (s, 3H, OCH_3), 6.83-7.40 (m, 13H, ArH), 7.64-7.67 (m, 2H, ArH), 8.36 (s, 1H, ArH), 8.38 (dd, *J* = 7.2, 1.8 Hz, 1H, ArH), 8.64 (dd, *J* = 7.2, 1.8 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 55.5 (OCH_3), 86.0 (C), 87.8 (C), 95.3 (d, J_{CF} = 3.4 Hz, C), 103.6 (C), 116.2 (CH), 116.4 (d, J_{CF} = 21.3 Hz, CH), 116.6 (CH), 118.7 (d, J_{CF} = 22.8 Hz, CH), 121.1 (C), 122.0 (2CH), 123.9 (C), 124.1 (C), 124.8 (CH), 124.9 (d, J_{CF} = 9.5 Hz, C), 126.2 (CH), 126.7 (CH), 127.8 (d, J_{CF} = 3.0 Hz, CH), 128.3 (CH), 128.4 (CH), 129.3 (C), 129.6 (CH), 129.7 (CH), 129.8 (2CH), 130.3 (d, J_{CF} = 8.6 Hz, CH), 131.0 (CH), 133.6 (C), 134.5 (C), 151.2 (C), 159.6 (C), 162.6 (d, $^1J_{CF}$ = 247 Hz, CF), 165.5 (C=O); ^{19}F NMR (282.40 MHz, $CDCl_3$): δ = -112.48 (ArF); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3058 (w), 2940 (w), 2834 (w), 2197 (w), 1715 (s), 1593 (w), 1573 (m), 1485 (m), 1369 (w), 1282 (m), 1218 (m), 1192 (s), 1156 (m), 1031 (m), 924 (w), 856 (m), 784 (m), 761 (s), 683 (s), 618 (w); MS (EI, 70 eV): *m/z* (%): 496 (M^+, 10), 404 (27), 403 (100), 375 (11), 332 (13), 331 (34), 285 (4), 166 (6), 147 (2), 94 (19), 69 (3), 65 (5), 43 (2); HRMS (EI) calcd for C_{34} H_{21} O_3 F [M^+]: 496.14692 found 496.14697.

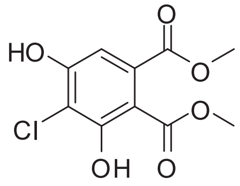
Phenyl 1-((3-methoxyphenyl)ethynyl)-4-(p-tolylethynyl)-2-naphthoate (16b):



Chemical Formula: $C_{35}H_{24}O_3$
Exact Mass: 492.17

Starting with **8** (272 mg, 0.50 mmol), Pd (PPh_3)$_4$ (10 mol%), dry CuI (20 mol%), triethylamine (126 mg, 1.25 mmol), Bu_4NI (553 mg, 1.5mmol), **13c** (73 mg, 0.55 mmol) was added in DMF (5mL per 1 mmol of **8**), and **13g** (75 mg, 0.65 mmol), **16b** was isolated after chromatography (silica gel, *n*-heptane/EtOAc) as green crystals (143 mg, 58%), mp. 148-149 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.29 (s, 3H, CH_3), 3.62 (s, 3H, OCH_3), 6.79-7.26 (m, 9H, ArH), 7.32-7.38 (m, 2H, ArH), 7.46 (td, *J* = 8.1, 1.7 Hz, 2H, ArH), 7.60-7.64 (m, 2H, ArH), 8.33 (s, 1H, ArH), 8.39 (dd, *J* = 7.1, 2.1 Hz, 1H, ArH), 8.61 (dd, *J* = 7.1, 2.1 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 21.8 (CH_3), 55.4 (OCH_3), 86.1 (C), 86.4 (C), 97.1 (C), 103.2 (C), 116.1 (CH), 116.5 (CH), 120.0 (C), 121.9 (C), 122.0 (2CH), 123.2 (C), 124.2 (C), 124.7 (CH), 126.1 (CH), 126.8 (CH), 128.2 (CH), 128.3 (CH), 129.3 (C), 129.4 (CH), 129.5 (2CH), 129.7 (CH), 129.8 (2CH), 130.5 (CH), 131.9 (2CH), 133.6 (C), 134.5 (C), 139.3 (C), 151.2 (C), 159.6 (C), 164.9 (C=O); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3055 (w), 2962 (w), 2832 (w), 2200 (w), 1740 (m), 1592 (m), 1488 (m), 1389 (w), 1332 (w), 1259 (m), 1198 (s), 1160 (s), 1132 (s), 1032 (s), 933 (m), 896 (m), 807 (m), 786 (s), 752 (s), 687 (s), 549 (w); MS (EI, 70 eV): *m/z* (%): 492 (M^+, 5), 399 (33), 378 (10), 4286 (37), 285 (100), 257 (16), 226 (15), 214 (22), 213 (46), 107 (7), 94 (14), 71 (5), 57 (8), 44 (11), 43 (14); HRMS (EI) calcd for C_{35} H_{24} O_3 [M^+]: 492.17200 found 492.17119.

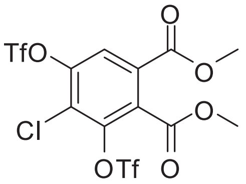
Procedure for synthesis of Dimethyl 4-chloro-3,5-dihydroxyphthalate (18):



Chemical Formula: $C_{10}H_9ClO_6$
Exact Mass: 260.01

Diene **3e** (463 mg, 1.5 mmol) was added to DMAD (319 mg, 0.27 mL, 2.25 mmol) at −78 °C. The mixture (neat) was allowed to warm to 20 °C during 20 h with stirring. To the mixture was added hydrochloric acid (10%) and dichloromethane (30 mL each). The organic and the aqueous layer were separated and the latter was extracted with CH_2Cl_2. The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in vacuo. The residue was purified by column chromatography to give **18** as a crystalline colourless solid (195 mg, 50%), mp. = 127-129 °C. ^{1}H NMR (250 MHz, $CDCl_3$): $\delta = 3.82$ (s, 3 H, OCH_3), 3.85 (s, 3 H, OCH_3), 6.57 (s, 1H, OH), 6.57 (s, 1H, ArH), 11.55 (s, 1H, OH). ^{13}C NMR (62.90 MHz, $CDCl_3$): $\delta = 52.8$ (OCH_3), 53.0 (OCH_3), 103.5 (C), 107.5 (CH), 109.3, 135.0 (C), 156.6, 158.7 (C-OH), 168.6, 169.0 (C=O). IR (ATR, cm^{-1}): v? = 2984 (w), 2954 (w), 2905 (w), 2847 (w), 1792 (w), 1722 (s), 1668 (m), 1435 (m), 1328 (m), 1243 (s), 1067 (s), 844 (m). MS (EI, 70 eV): *m/z* (%): 262 (M^+, ^{37}Cl, 9), 260 (M^+, ^{35}Cl, 15), 228 (53), 198 (23), 170 (100), 153 (23), 89 (25). Anal.: calcd (%) for $C_{10}H_9ClO_6$: C 46.08, H 3.48; found: C 46.21, H 3.31.

Procedure for synthesis of Dimethyl 4-chloro-3,5-bis(trifluoromethylsulfonyloxy)-phthalate (19):



Chemical Formula: $C_{12}H_7ClF_6O_{10}S_2$
Exact Mass: 523.91

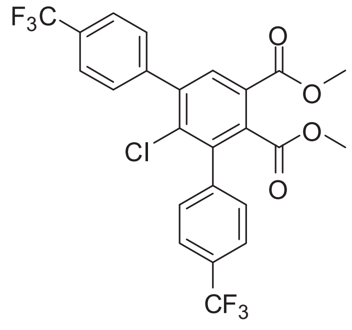
To a solution of **18** (1.0 equiv.) in CH_2Cl_2 (10 mL/mmol) was added pyridine (4.0 equiv) at – 78 °C under an argon atmosphere. After 10 min, Tf_2O (2.4 equiv) was added at -78 °C. The mixture was allowed to warm up to 0 °C and stirred for 4 h. The reaction mixture was filtered and the filtrate was concentrated in vacuo. The products of the reaction mixture were isolated by rapid column chromatography (flash silica gel, heptanes/EtOAc). Starting with **18** (2.080 g, 8.0 mmol), pyridine (2.6 mL, 32.0 mmol), CH_2Cl_2, and Tf_2O (3.2 mL, 19.2 mmol), **19** was isolated as viscous colourless oil (3.65 g, 87%). ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 3.86$ (s, 3 H, OCH_3), 3.88 (s, 3 H, OCH_3), 7.92 (s, 1H, ArH). ^{13}C NMR (62.90 MHz, $CDCl_3$): $\delta = 52.6$ (OCH_3), 52.7 (OCH_3), 117.5 (q, $^1J_{CF} = 321$ Hz, CF_3), 117.6 (q, $^1J_{CF} = 321$ Hz, CF_3), 123.0 (CH), 126.5, 128.7, 130.0, 142.4. 145.8 (C), 167.7 (2C, C=O). ^{19}F NMR (282.4 MHz. $CDCl_3$): $\delta = -71.99$ (CF_3), -73.20 (CF_3). IR

(ATR, cm^{-1}): *v*? = 3103 (w), 2960 (w), 2850 (w), 2054 (w), 1980 (w), 1739 (s), 1599 (w), 1567 (w), 1429 (s), 1395 (m), 1305 (m), 1277 (m), 1206 (s), 1129 (s), 1113 (s), 1005 (s), 961 (s), 919 (w), 859 (w), 820 (m), 787 (s), 751 (s), 732 (s), 698 (m), 651 (m), 593 (s), 574 (m). MS (EI, 70 eV): *m/z* (%): 524 (M$^+$, ^{35}Cl, 30), 493 (100), 460 (13), 429 (39), 391 (4), 365 (36), 299 (42), 271 (6), 238 (11), 199 (12), 171 (9), 143 (3), 84 (8), 69 (38), 59 (13). HRMS (EI) calcd for $C_{12}H_7O_{10}ClF_6S_2$ [M$^+$, ^{35}Cl]: 523.90679, found 523.907255.

General procedure for synthesis of 20a-g and 21a-e:

A 1,4-dioxane solution (4 mL per 0.3 mmol of **19**) of **19**, K_3PO_4, $Pd(PPh_3)_4$ and arylboronic acid **4** was stirred at 110 °C or 90 °C for 6 or 8 h for products **20** or **21** respectively. After cooling to 20 °C, a saturated aqueous solution of NH_4Cl was added. The organic and the aqueous layer were separated and the latter was extracted with $CH_2Cl_{2.}$ The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in vacuo. The residue was purified by column chromatography.

Dimethyl 4-chloro-3,5-di(4-trifluorophenyl)phthalate (20a):

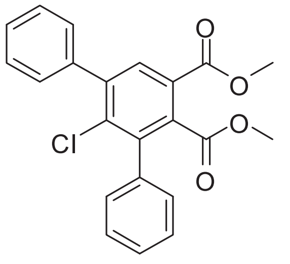


Chemical Formula: $C_{24}H_{15}ClF_6O_4$
Exact Mass: 516.06

Starting with **19** (157 mg, 0.3 mmol), K_3PO_4 (191 mg, 0.9 mmol), $Pd(PPh_3)_4$ (3 mol-%), boronic acid **4b** (137 mg, 0.72 mmol) and 1,4-dioxane (4 mL), **20a** was isolated as a colourless crystals (119 mg, 77%), mp. 190-191 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.50 (s, 3H, OCH_3), 3.85 (s, 3H, OCH_3), 7.38 (bd, *J* = 8.0 Hz, 2H, ArH), 7.51 (bd, *J* = 8.0 Hz, 2H, ArH), 7.62-7.69 (m, 4H, ArH), 7.98 (s, 1H, ArH). ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 52.7 (OCH_3), 53.1 (OCH_3), 124.2 (q, J_{CF} = 272 Hz, 2ArCF$_3$), 125.3 (q, J_{CF} = 3.8 Hz, 2CH), 125.6 (q, J_{CF} = 3.8 Hz, 2CH), 126.2 (C), 130.0 (2CH), 130.3 (2CH), 130.8 (q, J_{CF} = 32.6 Hz, C), 130.9 (q, J_{CF} = 32.6 Hz, C) 132.3 (CH) 136.9 (2C), 139.0 (C), 139.8 (C), 141.3 (C), 141.8 (C), 165.0 (CO), 167.5 (CO); ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -62.68 (2ArCF$_3$): IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3059 (w), 2962 (w), 2845 (w), 1737 (m), 1722 (s), 1617 (w), 1587 (w), 1551 (w), 1437 (w), 1321 (s), 1262 (s), 1237 (m), 1119 (s), 1105 (s), 1059 (s), 1016 (m), 964 (s), 842 (s), 792 (m), 685 (m), 612 (m); MS (EI, 70 eV): *m/z* (%): 518 (M$^+$, ^{37}Cl, 23), 517 (M$^+$+1, ^{35}Cl, 16), 516 (M$^+$, ^{35}Cl, 70), 487 (74), 486 (55), 485

(100), 453 (11), 451 (10), 398 (8), 351 (6), 343 (4), 294 (9), 248 (6), 147 (4), 84 (15), 49 (5); HRMS (EI) calcd for $C_{24}H_{15}O_4ClF_6$ [M$^+$, ^{35}Cl]: 516.05576, found 516.05576.

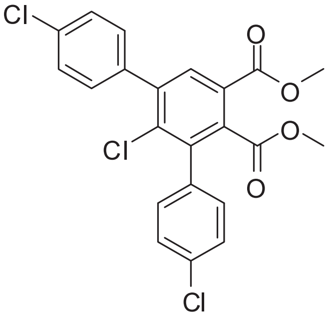
Dimethyl 4-chloro-3,5-di(phenyl)phthalate (20b):



Chemical Formula: $C_{22}H_{17}ClO_4$
Exact Mass: 380.08

Starting with **19** (157 mg, 0.3 mmol), K_3PO_4 (191 mg, 0.9 mmol), $Pd(PPh_3)_4$ (3 mol-%), boronic acid **4f** (88 mg, 0.72 mmol) and 1,4-dioxane (4 mL), **20b** was isolated as a white solid (85 mg, 75%), mp. 86-88 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.48 (s, 3H, OCH_3), 3.82 (s, 3H, OCH_3), 7.21-7.25 (m, 2H, ArH), 7.32-7.40 (m, 8H, ArH), 7.94 (s, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 52.5 (OCH_3), 52.9 (OCH_3), 125.7 (C), 128.2 (2CH), 128.5 (4CH), 129.5 (2CH), 129.8 (2CH), 132.0 (CH), 136.4 (C), 136.5 (C), 137.5 (C), 138.7 (C), 140.2 (C), 142.5 (C), 165.5 (CO), 168.1 (CO); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3055 (w), 2944 (w), 2925 (w), 2851 (w), 1722 (s), 1579 (w), 1554 (w), 1495 (w), 1434 (m), 1373 (w), 1339 (m), 1266 (s), 1238 (s), 1205 (m), 1146 (m), 1102 (m), 1071 (m), 967 (m), 909 (w), 890 (w), 795 (m), 765 (m), 697 (s), 637 (w), 580 (m); MS (GC, 70 eV): *m/z* (%): 382 (M$^+$, ^{37}Cl, 21), 381 (M$^+$+1, ^{35}Cl, 14), 380 (M$^+$, ^{35}Cl, 58), 351 (35), 350 (23), 349 (100), 317 (16), 290 (4), 262 (5), 226 (26), 213 (4), 113 (13), 100 (3), 59 (1); HRMS (EI) calcd for $C_{22}H_{17}O_4Cl$ [M$^+$, ^{35}Cl]: 380.08099, found 380.08116.

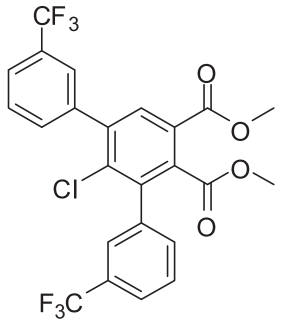
Dimethyl 4-chloro-3,5-di(4-chlorophenyl)phthalate (20c):



Chemical Formula: $C_{22}H_{15}Cl_3O_4$
Exact Mass: 448.00

Starting with **19** (157 mg, 0.3 mmol), K_3PO_4 (191 mg, 0.9 mmol), $Pd(PPh_3)_4$ (3 mol-%), boronic acid **4g** (112 mg, 0.72 mmol) and 1,4-dioxane (4 mL), **20c** was isolated as a white solid (85 mg, 63%), mp. 158-160 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.52 (s, 3H, OCH_3), 3.82 (s, 3H, OCH_3), 7.16 (td, *J* = 8.6, 2.1 Hz, 2H, ArH), 7.29-7.38 (m, 6H, ArH), 7.92 (s, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 52.7 (OCH_3), 53.0 (OCH_3), 126.0 (C), 128.6 (2CH), 128.8 (2CH), 130.9 (2CH), 131.2 (2CH), 132.1 (CH), 134.7 (C), 134.8 (2C), 136.7 (C), 136.8 (C), 137.3 (C), 139.1 (C), 141.4 (C), 165.2 (CO), 167.8 (CO); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3068 (w), 2950 (w), 2923 (w), 2851 (w), 1733 (s), 1720 (s), 1596 (w), 1583 (w), 1547 (w), 1489 (m), 1434 (m), 1345 (m), 1275 (s), 1262 (s), 1243 (s), 1178 (s), 1149 (m), 1085 (s), 1067 (m), 1014 (m), 962 (m), 919 (w), 890 (m), 825 (s), 785 (s), 719 (m), 692 (w), 598 (m); MS (EI, 70 eV): *m/z* (%): 452 (M^+, $^{37}Cl_2{}^{35}Cl$, 23), 450 (M^+, $^{37}Cl^{35}Cl_2$, 66), 448 (M^+, $^{35}Cl_3$, 66), 419 (99.9), 417 (100), 385 (10), 296 (8), 260 (14), 226 (7), 224 (13), 175 (3), 147 (3), 130 (7), 112 (8), 99 (3), 59 (2); HRMS (EI) calcd for $C_{22}H_{15}O_4Cl_3$ [M^+, $^{35}Cl_2\,^{37}Cl_1$]: 450.00009 found 450.00000.

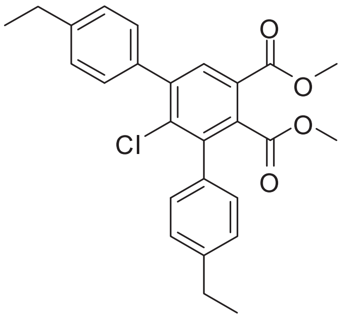
Dimethyl 4-chloro-3,5-di(3-trifluorophenyl)phthalate (20d):



Chemical Formula: $C_{24}H_{15}ClF_6O_4$
Exact Mass: 516.06

Starting with **19** (157 mg, 0.3 mmol), K_3PO_4 (191 mg, 0.9 mmol), $Pd(PPh_3)_4$ (3 mol-%), boronic acid **4o** (137 mg, 0.72 mmol) and 1,4-dioxane (4 mL), **20d** was isolated as a colourless crystals (76 mg, 49%), mp. 110-112 °C. ^1H NMR (300 MHz, $CDCl_3$): δ = 3.50 (s, 3H, OCH_3), 3.84 (s, 3H, OCH_3), 7.43-7.64 (m, 8H, ArH), 7.98 (s, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 52.6 (OCH_3), 53.1 (OCH_3), 124.1 (q, $^1J_{CF}$ = 272 Hz, $2ArCF_3$), 125.4 (q, J_{CF} = 3.8 Hz, CH), 125.5 (q, J_{CF} = 3.8 Hz, CH), 126.3 (2C), 126.4 (q, J_{CF} = 3.8 Hz, CH), 126.7 (q, J_{CF} = 3.8 Hz, CH), 128.9 (CH), 129.1 (CH), 130.8 (q, J_{CF} = 32.5 Hz, C), 131.5 (q, J_{CF} = 32.5 Hz, C), 132.4 (CH), 132.9 (CH), 133.4 (CH), 136.9 (C), 137.1 (C), 138.9 (C), 139.0 (C), 141.2(C), 165.0 (CO), 167.5 (CO); ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -62.62, -62.68 ($2ArCF_3$); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3070 (w), 2954 (w), 2850 (w), 1738 (s), 1726 (m), 1588 (w), 1556 (w), 1439 (w), 1324 (s), 1262 (s), 1237 (m), 1118 (s), 1074 (s), 1066 (s), 964 (m), 840 (w), 790 (m), 704 (s), 665 (m), 565 (m); MS (EI, 70 eV): *m/z* (%): 518 (M^+, ^{37}Cl, 20), 517 (M^++1, ^{35}Cl, 14), 516 (M^+, ^{35}Cl, 65), 487 (71), 486 (51), 485 (100), 398 (8), 379 (5), 351 (6), 294 (7), 248 (5), 145 (3), 97 (6), 86 (8), 84 (14), 57 (13), 43 (10). HRMS (EI) calcd for $C_{24}H_{15}O_4ClF_6$ [M^+, ^{35}Cl]: 516.05576, found 516.05613.

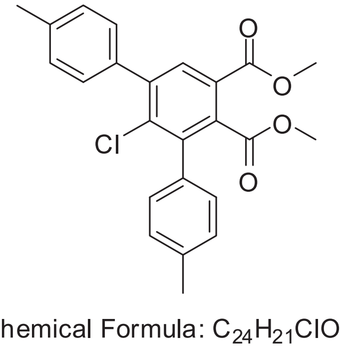
Dimethyl 4-chloro-3,5-di(4-ethylphenyl)phthalate (20e):



Chemical Formula: $C_{26}H_{25}ClO_4$
Exact Mass: 436.14

Starting with **19** (157 mg, 0.3 mmol), K_3PO_4 (191 mg, 0.9 mmol), $Pd(PPh_3)_4$ (3 mol-%), boronic acid **4p** (108 mg, 0.72 mmol) and 1,4-dioxane (4 mL), **20e** was isolated as a white solid (88 mg, 67%), mp. 116-118 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.20 (t, *J* = 7.6 Hz, 3H, CH_3), 1.21 (t, *J* = 7.6 Hz, 3H, CH_3), 2.62 (q, *J* = 7.6 Hz, 2H, CH_2), 2.64 (q, *J* = 7.6 Hz, 2H, CH_2), 3.48 (s, 3H, OCH_3), 3.80 (s, 3H, OCH_3), 7.12-7.23 (m, 6H, ArH), 7.30 (td, *J* = 8.2, 2.0 Hz, 2H, ArH), 7.92 (s, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 15.4 (CH_3), 15.6 (CH_3), 28.8 ($2CH_2$), 52.4 (OCH_3), 52.8 (OCH_3), 125.5 (C), 127.6 (2CH), 127.9 (2CH), 129.5 (2CH), 129.7 (2CH), 131.9 (CH), 133.8 (C), 136.1 (C), 136.3 (C), 137.6 (C), 140.2 (C), 142.4 (C), 144.4 (C), 144.6 (C), 165.6 (CO), 168.3 (CO); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3025 (w), 2962 (w), 2930 (w), 2872 (w), 1727 (s), 1611 (w), 1584 (w), 1552 (w), 1512 (m), 1434 (m), 1373 (w), 1340 (m), 1259 (s), 1236 (s), 1197 (m), 1145 (s), 1103 (m), 1069 (s), 1020 (m), 968 (m), 910 (w), 889 (m), 831 (m), 790 (m), 730 (m), 628 (m), 564 (m); MS (GC, 70 eV): *m/z* (%): 439 (M^++1, ^{37}Cl, 10), 438 (M^+, ^{37}Cl, 37), 437 (M^++1, ^{35}Cl, 30), 436 (M^+, ^{35}Cl, 100), 421 (19), 407 (27), 405 (51), 373 (15), 345 (7), 303 (4), 275 (2), 254 (5), 252 (8), 239 (9), 203 (5), 126 (6), 120 (4), 29 (2); HRMS (EI) calcd for $C_{26}H_{25}O_4Cl$ [M^+, ^{35}Cl]: 436.14359, found 436.14368.

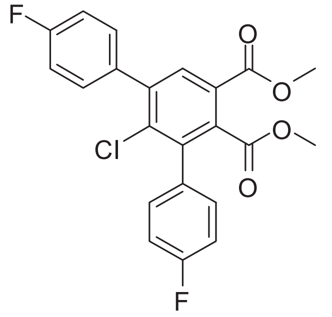
Dimethyl 4-chloro-3,5-di(*p*-tolyl)phthalate (20f):



Chemical Formula: $C_{24}H_{21}ClO_4$
Exact Mass: 408.11

Starting with **19** (157 mg, 0.3 mmol), K_3PO_4 (191 mg, 0.9 mmol), $Pd(PPh_3)_4$ (3 mol-%), boronic acid **4c** (98 mg, 0.72 mmol) and 1,4-dioxane (4 mL), **20f** was isolated as a colourless solid (88 mg, 72%), mp. 139-141 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.33 (s, 3H, CH_3), 2.35 (s, 3H, CH_3), 3.51 (s, 3H, OCH_3), 3.82 (s, 3H, OCH_3), 7.10-7.18 (m, 4H, ArH), 7.21-7.29 (m, 4H, ArH), 7.91 (s, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 21.3 (CH_3), 21.4 (CH_3), 52.3 (OCH_3), 52.6 (OCH_3), 125.3 (C), 128.7 (2CH), 128.9 (2CH), 129.2 (2CH), 129.4 (2CH), 131.7 (CH), 133.4 (C), 135.7 (C), 136.1 (C), 137.4 (C), 138.0 (C), 138.1 (C), 140.0 (C), 142.2 (C), 165.3 (CO), 168.0 (CO); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3026 (w), 2949 (w), 2922 (w), 2859 (w), 2253 (w), 1906 (w), 1727 (s), 1613 (w), 1584 (w), 1552 (w), 1514 (m), 1434 (m), 1373 (w), 1340 (m), 1259 (s), 1237 (s), 1213 (m), 1145 (m), 1104 (m), 1069 (m), 1021 (m), 969 (m), 909 (m), 890 (m), 814 (m), 783 (m), 730 (m), 720 (m), 634 (m), 554 (m); MS (EI, 70 eV): *m/z* (%): 411 (M^++1, ^{37}Cl, 9), 410 (M^+, ^{37}Cl, 36), 409 (M^++1, ^{35}Cl, 26), 408 (M^+, ^{35}Cl, 97), 380 (8), 379 (35), 378 (25), 377 (100), 347 (8), 345 (23), 318 (3), 290 (4), 289 (5), 255 (8), 239 (15), 226 (4), 204 (7), 178 (3), 126(9), 91 (2), 59 (1); HRMS (EI) calcd for $C_{24}H_{21}O_4Cl$ [M^+, ^{35}Cl]: 408.11229, found 408.112793.

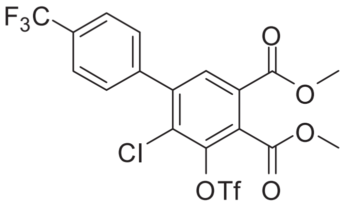
Dimethyl 4-chloro-3,5-di(4-fluorophenyl)phthalate (20g):



Chemical Formula: $C_{22}H_{15}ClF_2O_4$
Exact Mass: 416.06

Starting with **19** (157 mg, 0.3 mmol), K_3PO_4 (191 mg, 0.9 mmol), $Pd(PPh_3)_4$ (3 mol-%), boronic acid **4q** (101 mg, 0.72 mmol) and 1,4-dioxane (4 mL), **20g** was isolated as a yellowish solid (82 mg, 66%), mp. 134-136 °C; ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.52 (s, 3H, OCH_3), 3.843 (s, 3H, OCH_3), 7.01-7.11 (m, 4H, ArH), 7.17-7.23 (m, 2H, ArH), 7.32-7.38 (m, 2H, ArH), 7.93 (s, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 52.6 (OCH_3), 53.0 (OCH_3), 115.4 (d, J_{CF} = 21.7 Hz, 2CH), 115.6 (d, J_{CF} = 21.7 Hz, 2CH), 125.8 (C), 131.3 (d, J_{CF} = 8.3 Hz, 2CH), 131.7 (d, J_{CF} = 8.3 Hz, 2CH), 132.1 (CH), 132.2 (d, J_{CF} = 3.4 Hz, C), 134.5 (d, J_{CF} = 3.4 Hz, C), 136.7 (C), 137.7 (C), 139.3 (C), 141.5 (C), 162.8 (d, $^1J_{CF}$ = 248 Hz, CF), 162.9 (d, $^1J_{CF}$ = 248 Hz, CF), 165.3 (CO), 167.9 (CO); ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -112.99, -113.16 (2ArF); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3036 (w), 2952 (w), 2851 (w), 1724 (s), 1603 (m), 1550 (w), 1507 (s), 1436 (m), 1337 (m), 1276 (s), 1261 (s), 1219 (s), 1149 (s), 1103 (s), 1094 (s), 965 (m), 838 (s), 787 (s), 629 (w), 552 (s); MS (EI, 70 eV): *m/z* (%): 418 (M^+, ^{37}Cl, 21), 417 (M^++1, ^{35}Cl, 14), 416 (M^+, ^{35}Cl, 60), 387 (35), 386 (23), 385 (100), 325 (2), 298 (7), 262 (21), 251 (7), 176 (2), 131 (7), 121 (2), 59 (2); HRMS (EI) calcd for $C_{22}H_{15}O_4ClF_2$ [M^+, ^{35}Cl]: 416.06214, found 416.06241.

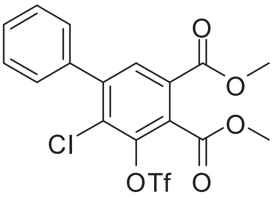
Dimethyl 4-chloro-3-(4-trifluoromethylphenyl)-5-(trifluoromethylsulfonyl-oxy)phthalate (21a):



Chemical Formula: $C_{18}H_{11}ClF_6O_7S$
Exact Mass: 519.98

Starting with **19** (157 mg, 0.3 mmol), K_3PO_4 (95.4 mg, 0.45 mmol), $Pd(PPh_3)_4$ (3 mol-%), boronic acid **4b** (63 mg, 0.33 mmol) and 1,4-dioxane (4 mL), **21a** was isolated as a colourless semisolid (98 mg, 63%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.85 (s, 3H, OCH_3), 3.92 (s, 3H, OCH_3), 7.49 (d, J = 8.1 Hz, 2H, ArH), 7.69 (d, J = 8.1 Hz, 2H, ArH), 7.91 (s, 1H, ArH). ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 53.5 (OCH_3), 53.7 (OCH_3), 118.7 (q, $^1J_{CF}$ = 321 Hz, CF_3), 124.0 (q, $^1J_{CF}$ = 272 Hz, $ArCF_3$), 125.9 (q, J_{CF} = 3.8 Hz, 2CH), 128.9 (C), 129.9 (2CH), 130.2 (C), 130.7 (C), 131.5 (q, J_{CF} = 32.5 Hz, C), 131.7 (CH), 140.3 (C), 142.9 (C), 143.3 (C), 163.9 (CO), 164.2 (CO). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -62.81 ($ArCF_3$), –71.77 (CF_3). IR (ATR, cm^{-1}): $\tilde{\nu}$ = 2957 (w), 2925 (w), 2853 (w), 1735 (s), 1601 (w), 1547 (w), 1428 (m), 1321 (m), 1270 (s), 1215 (s), 1167 (s), 1125 (s), 1065 (s), 1008 (m), 969 (w), 834 (w), 798 (m), 686 (w), 598 (m); MS (EI, 70 eV): *m/z* (%): 522 (M$^+$, ^{37}Cl, 23), 520 (M$^+$, ^{35}Cl, 63), 491 (34), 489 (100), 427 (14), 425 (43), 387 (21), 359 (37), 356 (23), 300 (10), 298 (25), 241 (10), 207 (8), 97 (7), 69 (15), 57 (12); HRMS (EI) calcd for $C_{18}H_{11}O_7ClF_6S$ [M$^+$, ^{35}Cl]: 519.98127, found 519.98153.

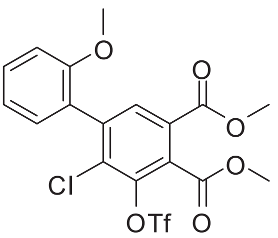
Dimethyl 4-chloro-3-(phenyl)-5-(trifluoromethylsulfonyl-oxy)phthalate (21b):



Chemical Formula: $C_{17}H_{12}ClF_3O_7S$
Exact Mass: 451.99

Starting with **19** (157 mg, 0.3 mmol), K_3PO_4 (95.4 mg, 0.45 mmol), $Pd(PPh_3)_4$ (3 mol-%), boronic acid **4f** (40 mg, 0.33 mmol) and 1,4-dioxane (4 mL), **21b** was isolated as a colourless semisolid (88 mg, 65%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.84 (s, 3H, OCH_3), 3.91 (s, 3H, OCH_3), 7.32-7.42 (m, 5H, ArH), 7.90 (s, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 53.4 (OCH_3), 53.6 (OCH_3), 118.6 (q, $^1J_{CF}$ = 321 Hz, CF_3), 128.7 (C), 128.8 (2CH), 129.3 (CH), 129.4 (2CH), 129.9 (C), 131.6 (C), 131.9 (CH), 136.8 (C), 142.8 (C), 144.8 (C), 164.1 (CO), 164.5 (CO); ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –71.86 (CF_3); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 2955 (w), 2924 (w), 2851 (w), 1731 (s), 1598 (w), 1545 (w), 1424 (s), 1319 (m), 1268 (s), 1207 (s), 1167 (m), 1123 (s), 1098 (m), 1002 (m), 968(w), 832 (m), 790 (s), 698 (m), 641 (w), 597 (m), 579 (w); MS (GC, 70 eV): *m/z* (%): 454 (M$^+$, ^{37}Cl, 39), 452 (M^+, ^{35}Cl, 100), 421 (60), 357 (30), 319 (29), 291 (31), 263 (15), 260 (18), 230 (29), 229 (19), 173 (15), 139 (16), 138 (11), 69 (13), 59 (5); HRMS (EI) calcd for $C_{17}H_{12}O_7ClF_3S$ [M^+, ^{35}Cl]: 451.99389, found 451.99357.

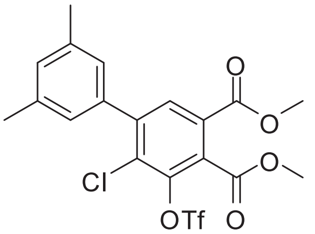
Dimethyl 4-chloro-3-(2-methoxyphenyl)-5-(trifluoromethylsulfonyl-oxy)phthalate (21c):



Chemical Formula: $C_{18}H_{14}ClF_3O_8S$
Exact Mass: 482.01

Starting with **19** (157 mg, 0.3 mmol), K_3PO_4 (95.4 mg, 0.45 mmol), $Pd(PPh_3)_4$ (3 mol-%), boronic acid **4j** (50 mg, 0.33 mmol) and 1,4-dioxane (4 mL), **21c** was isolated as a colourless solid (68 mg, 47%), mp. 103-105 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.70 (s, 3H, OCH_3), 3.82 (s, 3H, OCH_3), 3.91 (s, 3H, OCH_3), 6.92 (d, *J* = 8.4 Hz, 1H, ArH), 6.98 (dt, *J* = 7.4, 1.0 Hz, 1H, ArH), 7.11 (dd, *J* = 7.5, 1.7 Hz, 1H, ArH), 7.37 (dt, *J* = 7.8, 1.7 Hz, 1H, ArH), 7.86 (s, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 52.0 (OCH_3), 52.3 (OCH_3), 54.9 (OCH_3), 110.0 (CH), 117.5 (q, $^1J_{CF}$ = 321 Hz, CF_3), 119.5 (CH), 124.7 (C), 127.0 (C), 128.5, (C), 129.3 (CH), 129.8 (CH), 131.2 (CH), 131.9 (C), 141.2 (C), 141.3 (C), 155.4 (C), 163.1 (CO), 163.4 (CO); ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = −71.99 (CF_3); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 2955 (w), 2923 (w), 2849 (w), 1738 (s), 1730 (m), 1607 (w), 1582 (w), 1501 (w), 1468 (w), 1429 (w), 1325 (w), 1270 (s), 1242 (m), 1210 (m), 1164 (w), 1135 (m), 1112 (w), 1009 (w), 926 (w), 806 (m), 755 (m), 672 (w), 639 (w), 598 (m), 572 (w), 547 (w), 573 (w); MS (EI, 70 eV): *m/z* (%): 484 (M^+, ^{37}Cl, 40), 482 (M^+, ^{35}Cl, 100), 451 (25), 415 (2), 387 (4), 317 (27), 289 (20), 250 (16), 229 (5), 195 (6), 168 (6), 139 (6), 69 (9), 59 (5); HRMS (EI) calcd for $C_{18}H_{14}O_8ClF_3S$ [M^+, ^{35}Cl]: 482.00445, found 482.005219.

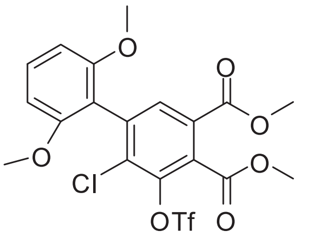
Dimethyl 4-chloro-3-(3,5-dimethylphenyl)-5-(trifluoromethylsulfonyl-oxy)phthalate (21d):



Chemical Formula: $C_{19}H_{16}ClF_3O_7S$
Exact Mass: 480.03

Starting with **19** (157 mg, 0.3 mmol), K_3PO_4 (95.4 mg, 0.45 mmol), $Pd(PPh_3)_4$ (3 mol-%), boronic acid **4d** (50 mg, 0.33 mmol) and 1,4-dioxane (4 mL), **21d** was isolated as a white solid (88 mg, 61%), mp. 79-81 °C; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.30 (s, 6H, $2CH_3$), 3.83 (s, 3H, OCH_3), 3.91 (s, 3H, OCH_3), 6.94 (brs, 2H, ArH), 7.02 (brs, 1H, ArH), 7.88 (s, 1H, ArH); ^{13}C NMR (62.89 MHz, CDCl$_3$): δ = 21.5 (2CH$_3$), 53.3 (OCH$_3$), 53.6 (OCH$_3$), 118.7 (q, $^1J_{CF}$ = 321 Hz, CF$_3$), 127.0 (2CH), 128.5 (C), 129.6 (C), 130.9 (CH), 131.6 (C), 131.9 (CH), 136.7 (C), 138.4 (2C), 142.8 (C), 145.2 (C), 164.2 (CO), 164.5 (CO); ^{19}F NMR (282.4 MHz, CDCl$_3$): δ = −71.88 (CF$_3$); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 2954 (w), 2923 (w), 2856 (w), 1732 (s), 1600 (w), 1545 (w), 1426 (s), 1332 (m), 1271 (s), 1208 (s), 1166 (m), 1131 (s), 1099 (m), 1004 (m), 970 (w), 813 (s), 790 (m), 670 (w), 596 (m); MS (GC, 70 eV): *m/z* (%): 482 (M$^+$, ^{37}Cl, 40), 480 (M$^+$, ^{35}Cl, 100), 449 (32), 319 (21), 315 (16), 291 (14), 288 (15), 258 (19), 230 (8), 201 (9), 165 (15), 152 (7), 139 (4), 77 (2), 69 (11); HRMS (EI) calcd for C$_{19}$H$_{16}$O$_7$ClF$_3$S [M$^+$, ^{35}Cl]: 480.02519, found 480.02524.

Dimethyl 4-chloro-3-(2,6-dimethoxyphenyl)-5-(trifluoromethylsulfonyl-oxy) phthalate (21e):



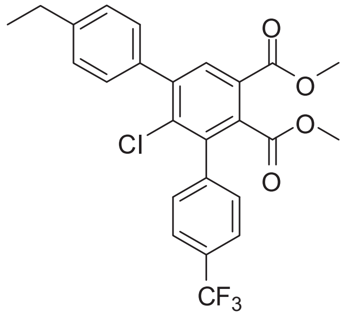
Chemical Formula: $C_{19}H_{16}ClF_3O_9S$
Exact Mass: 512.02

Starting with **19** (157 mg, 0.3 mmol), K$_3$PO$_4$ (95.4 mg, 0.45 mmol), Pd(PPh$_3$)$_4$ (3 mol-%), boronic acid **5** (60 mg, 0.33 mmol) and 1,4-dioxane (4 mL), **21e** was isolated as a colourless semisolid (74 mg, 48%); ^{1}H NMR (300 MHz, CDCl$_3$): δ = 3.65 (s, 6H, 2OCH$_3$), 3.81 (s, 3H, OCH$_3$), 3.91 (s, 3H, OCH$_3$), 6.57 (d, *J* = 8.4 Hz, 2H, ArH), 7.30 (t, *J* = 8.4 Hz, 1H, ArH), 7.80 (s, 1H, ArH). ^{13}C NMR (62.89 MHz, CDCl$_3$): δ = 53.2 (OCH$_3$), 53.5 (OCH$_3$), 56.0 (2OCH$_3$), 104.1 (2CH), 114.3 (C), 118.7 (q, $^1J_{CF}$ = 321 Hz, CF$_3$), 128.1, (C), 129.4 (C), 131.1 (CH), 133.7 (CH), 134.0 (C), 139.1 (C), 142.6 (C), 157.6 (2C), 164.6 (CO), 164.8 (CO); ^{19}F NMR (282.4 MHz, CDCl$_3$): δ = −72.09 (CF$_3$); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3005 (w), 2953 (w), 2841 (w), 1731 (s), 1602 (w), 1589 (m), 1426 (s), 1314 (m), 1268 (m), 1208 (s), 1166 (m), 1134 (m), 1107 (s), 1003 (m), 969 (w), 792 (s), 676 (w), 597 (m); MS (EI, 70 eV): *m/z* (%): 514 (M$^+$, ^{37}Cl, 34), 512 (M$^+$, ^{35}Cl, 100), 481 (14), 426 (17), 395 (21), 348 (20), 347 (54), 291 (15), 283 (13), 240 (7), 226 (10), 197 (8), 127 (7), 69 (44), 59 (26), 45 (20), 44 (8); HRMS (EI) calcd for C$_{19}$H$_{16}$O$_9$ClF$_3$S [M$^+$, ^{35}Cl]: 512.01502, found 512.01506.

General procedure for the synthesis of 22a,b:

The reaction was carried out in a pressure tube. To a dioxane suspension (4 mL) of **19** (236 mg, 0.45 mmol), $Pd(PPh_3)_4$ (3 mol %) and $Ar^1B(OH)_2$ (0.5 mmol) was added K_3PO_4 (143 mg, 0.67 mmol), and the resultant solution was degassed by bubbling argon through the solution for 10 min. The mixture was heated at 90 °C under Argon atmosphere for 8 h. The mixture was cooled to 20 °C. $Ar^2B(OH)_2$ (0.6 mmol) and K_3PO_4 (143 mg, 0.67 mmol) were added. The reaction mixtures were heated under an Argon atmosphere for 6 h at 110 °C. They were diluted with water and extracted with CH_2Cl_2 (3 X 25 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in vacuo. The residue was purified by flash chromatography (silica gel, EtOAc/heptanes).

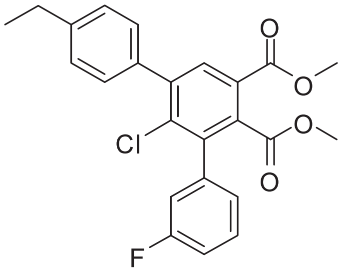
Dimethyl 4-chloro-3-(4-ethylphenyl)-5-(4-trifluorophenyl)phthalate (22a):



Chemical Formula: $C_{25}H_{20}ClF_3O_4$
Exact Mass: 476.10

Starting with **19** (236 mg, 0.45 mmol), K_3PO_4 (286 mg, 1.35 mmol), $Pd(PPh_3)_4$ (3 mol-%), boronic acid **4p** (75 mg, 0.5 mmol), 1,4-dioxane (4 mL), and boronic acid **4b** (114 mg, 0.6 mmol), **22a** was isolated as colourless crystals (122 mg, 57%), mp. 138-140 °C; ^{1}H NMR (300MHz, $CDCl_3$): δ = 1.22 (t, J = 7.8 Hz, 3H, CH_3), 2.65 (q, J = 7.5 Hz, 2H, CH_2), 3.48 (s, 3H, OCH_3), 3.82 (s, 3H, OCH_3), 7.21-7.32 (m, 4H, ArH), 7.35-7.38 (m, 2H, ArH), 7.60-7.63 (m, 2H, ArH), 7.97 (s, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 15.3 (CH_3), 28.6 (CH_2), 52.4 (OCH_3), 52.7 (OCH_3), 124.0 (q, J_{CF} = 272 Hz, CF_3), 125.0 (q, J_{CF} = 3.7 Hz, 2CH), 125.7 (C), 127.8 (2CH), 129.2 (2CH), 130.2 (2CH), 130.6 (q, J_{CF} = 32.5 Hz, C), 132.4 (CH), 135.4 (C), 135.8 (C), 136.8 (C), 138.5 (C), 140.0 (q, J_{CF} =1.4 Hz, C), 142.5 (C), 144.6 (C), 165.1 (CO), 167.6 (CO); ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = –62.7 (CF_3); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3026 (w), 2949 (w), 2922 (w), 2859 (w), 2253 (w), 1906 (w), 1727 (s), 1613 (w), 1584 (w), 1552 (w), 1514 (m), 1434 (m), 1373 (w), 1340 (m), 1259 (s), 1237 (s), 1213 (m), 1145 (m), 1104 (m), 1069 (m), 1021 (m), 969 (m), 909 (m), 890 (m), 814 (m), 783 (m), 730 (m), 720 (m), 634 (m), 554 (m); MS (EI, 70 eV): *m/z* (%): 479 (M^++1, ^{37}Cl, 9), 478 (M^+, ^{37}Cl, 36), 477 (M^++1, ^{35}Cl, 29), 476 (M^+, ^{35}Cl, 99), 461 (30), 447 (41), 445 (100), 415 (5), 387 (4), 343 (5), 309 (7), 239 (6), 215 (8), 199 (4), 163 (1), 151 (3), 119 (4), 59 (2), 29 (1); HRMS (ESI, pos) calcd for $C_{25}H_{21}F_3O_4Cl$ [M+H, ^{35}Cl]$^+$: 477.10683 found 477.10677, and $C_{25}H_{20}F_3NaO_4Cl$ [M + Na, ^{35}Cl]$^+$: 499.08932.

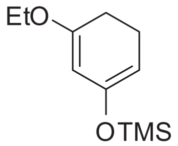
Dimethyl 4-chloro-3-(4-ethylphenyl)-5-(3-fluorophenyl)phthalate (22b):



Chemical Formula: $C_{24}H_{20}ClFO_4$
Exact Mass: 426.10

Starting with **19** (236 mg, 0.45 mmol), K_3PO_4 (286 mg, 1.35 mmol), $Pd(PPh_3)_4$ (3 mol-%), boronic acid **4p** (75 mg, 0.5 mmol), 1,4-dioxane (4 mL), and boronic acid **4a** (84 mg, 0.6 mmol), **22b** was isolated as colourless crystals (102 mg, 53%), mp. 80-82 °C; ^{1}H NMR (250 MHz, $CDCl_3$): $\delta = 1.22$ (t, $J = 7.6$ Hz, 3H, CH_3), 2.65 (q, $J = 7.6$ Hz, 2H, CH_2), 3.52 (s, 3H, OCH_3), 3.82 (s, 3H, OCH_3), 6.99-7.03 (m, 2H, ArH), 7.15 (d, $J = 6.3$ Hz, 1H, ArH), 7.22 (td, $J = 8.4, 2.1$ Hz, 2H, ArH), 7.28-7.33 (m, 3H, ArH), 7.95 (s, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): $\delta =$ 15.6 (CH_3), 28.8 (CH_2), 52.6 (OCH_3), 52.9 (OCH_3), 115.6 (d, $J_{CF} = 21.0$ Hz, CH), 117.2 (d, $J_{CF} = 22.0$ Hz, CH), 125.7 (d, $J_{CF} = 3.0$ Hz, CH), 125.8 (C), 128.0 (2CH), 129.5 (2CH), 129.8 (d, $J_{CF} = 8.3$ Hz, CH), 132.4 (CH), 135.8 (C), 136.1 (C), 137.2 (C), 138.5 (d, $J_{CF} = 8.4$ Hz, C), 138.8 (d, $J_{CF} = 1.9$ Hz, C), 142.7 (C), 144.8 (C), 162.5 (d, $^1J_{CF} = 248$ Hz, CF), 165.4 (CO), 167.9 (CO); ^{19}F NMR (282.4 MHz, $CDCl_3$): $\delta = -113.03$ (ArF); IR (ATR, cm^{-1}): $\tilde{\nu} = 3026$ (w), 2950 (w), 2873 (w), 1723 (s), 1612 (w), 1583 (w), 1553 (w), 1513 (w), 1434 (m), 1374 (w), 1341 (m), 1260 (s), 1243 (s), 1192 (m), 1165 (s), 1135 (s), 1063 (m), 1019 (w), 969 (m), 834 (m), 792 (m), 698 (s), 623 (w), 586 (w); MS (GC, 70 eV): *m/z* (%): 428 (M^+, ^{37}Cl, 32), 427 (M^++1, ^{35}Cl, 23), 426 (M^+, ^{35}Cl, 82), 411 (23), 397 (42), 396 (25), 395 (100), 363 (5), 293 (6), 257 (16), 190 (9), 128 (10), 122 (3), 118 (2), 59 (2); HRMS (EI) calcd for $C_{24}H_{20}O_4ClF$ [M^+, ^{35}Cl]: 426.10287, found 426.10279.

Procedure for synthesis of (5-ethoxycyclohexa-1,5-dienyloxy)trimethylsilane (Diene 25)[91a]



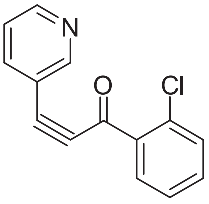
Chemical Formula: $C_{11}H_{20}O_2Si$
Exact Mass: 212.12

To a flask containing LDA (1.2 equiv., 1.0 M) was added a solution of enol ether (1 equiv) in THF (0.5 mL per mmol enol ether) at -78°C. After 10 min, TMSCl (1.2 equiv.) was added. After 1 h, the reaction was warmed to rt, poured into a cold solution of $NaHCO_3$ (10 mL per mmol, 5% aq.) extracted with Et_2O (20 mL per mmol), and washed with H_2O (3 x 10 mL per mmol) and sat. aq. NaCl (20 mL per mmol). The dried extract ($MgSO_4$) was concentrated *in vacuo* to give known[11a] silyl enol ether as pale yellow oil.

General procedure for the synthesis of Acetylenes 31 and 34[91e]:

To a pressure tube containing bromide (pyridyl or pyrimidyl) (10 mmol) was added bis triphenyl phosphine palladium dichloride (5 mol %), copper iodide (10 mol%), diisopropyl amine (10ml) and trimethylsilylacetylene (12 mmol). The reaction was stirred at 60 °C for 2 h then TBAF (10 mL, 10 mmol, 1.0M in THF) was added at 0 °C. After 30 min the solution was quenched with sat. aq. NH_4Cl (50 mL), extracted with dichloromethane (2 X 50mL). The dried extract ($MgSO_4$) was purified by chromatography eluting with EtOAc / Heptane to give the known compounds **31**[92] (as colorless crystals) and **34**[93] (as brown liquid) .

Procedure for the synthesis of 1-(2-chlorophenyl)-3-(pyridin-3-yl)prop-2-yn-1-one (36)[91b]:



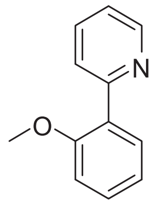
Chemical Formula: $C_{14}H_8ClNO$
Exact Mass: 241.03

To a stirred solution of **28** (206 mg, 2.0 mmol) and THF (10 mL) was added diisopropyl amine (1.1 equiv., 0.31 mL), then at 0°C was added n-BuLi (1.08 equiv., 2.5 M in hexanes, 0.86 mL). Then after 20 min freshly distilled 2-chloro benzoyl chloride (1.27 mL, 10 mmol) was added slowly at -78°C. After 1 h, the solution was allowed to warm to rt. After an additional 1 h, the mixture was quenched with sat. aq. $NaHCO_3$ (15 mL), diluted with EtOAc (15 mL), and washed with H_2O (2 x 15 mL) and sat. aq. NaCl (15 mL). The dried extract ($MgSO_4$) was concentrated *in vacuo* and purified by chromatography over silica gel, eluting with EtOAc / Hexanes to give **36** (357 mg, 74%) as a dark red viscous liquid. ^1H NMR (250 MHz, $CDCl_3$): δ = 7.25-7.42 (m, 4H, ArH), 7.84 (td, *J* = 7.9, 1.9 Hz, 1H, ArH) , 7.96-7.99 (m, 1H, ArH), 8.59 (dd, *J* = 4.9, 1.6 Hz, 1H, ArH), 8.77 (d, *J* = 1.4 Hz, 1H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 89.9 (C), 90.8 (C), 117.6 (CH), 123.5 (CH), 127.1 (CH), 131.8 (CH), 132.8 (CH), 133.8 (C), 133.9 (CH), 135.5 (C), 140.1 (CH), 151.0 (CH), 153.4 (CH), 176.4 (CO); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3061 (w), 2928 (w), 2854 (w), 2198 (s), 1646 (m), 1584 (s), 1473 (m), 1407 (m), 1297 (s), 1208 (s), 1188 (m), 1071 (m), 1021 (m), 998 (m), 819 (w), 738 (s), 700 (s), 629 (s); MS (GC, 70 eV): *m/z* (%): 243 (M^+, ^{37}Cl, 15), 241 (M^+, ^{35}Cl, 50), 215 (36), 213 (100), 178 (14), 151 (10), 130 (80), 111 (12), 102 (12), 75 (20), 50 (5); HRMS (EI) calcd for $C_{14}H_8NOCl$ [M^+, ^{35}Cl]: 241.02889, found 241.02891.

General procedure for the synthesis of Biaryls[91e] (27,29,32,35,37)a-c:

To a pressure tube containing acetylene (1 equiv) was added diene (1.5 or 3 equiv). The reaction mixture was stirred at 140 °C for 2-16 h. In the case of diene **23** the the reaction mixture was directly then subjected to purification by chromatography over silica gel eluting with EtOAc / Heptane to give the product but in the case of diene **24** and **25**, MeOH (5 mL) and K_2CO_3 (5 mmol) was added at r.t. After Stirring for 15 min the solution was quenched with sat. aq. NH_4Cl (30 mL), and then extracted with dichloromethane (2 X 50mL). The dried extract ($MgSO_4$) was purified by chromatography over silica gel eluting with EtOAc / Heptane to give the product.

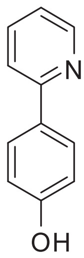
2-(2-Methoxyphenyl)pyridine (27a):



Chemical Formula: $C_{12}H_{11}NO$
Exact Mass: 185.08

Starting with 2-ethynyl pyridine **26** (0.13 mL, 2.0 mmol) and diene **23** (0.35 mL, 3.0 mmol), **27a** was isolated as colorless viscous liquid (233 mg, 63%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.77 (s, 3H, OCH_3), 6.93 (d, *J* = 8.3 Hz, 1H, ArH) , 7.01 (dt, *J* = 7.5, 1.0 Hz, 1H, ArH), 7.12 (dd, *J* = 7.4, 4.9, Hz, 1H, ArH), 7.27-7.33 (m, 1H, ArH), 7.61 (dt, *J* = 7.9, 1.9 Hz, 1H, ArH), 7.70 (dd, *J* = 7.6, 1.8 Hz, 1H, ArH), 7.74 (td, *J* = 8.0, 1.1 Hz, 1H, ArH), 8.63 (d, *J* = 4.8 Hz, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 55.5 (OCH_3), 111.3 (CH), 120.9 (CH), 121.5 (CH), 125.0 (CH), 129.0 (C), 129.8 (CH), 131.0 (CH), 135.5 (CH), 149.3 (CH), 156.0 (C), 156.8 (C); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3049 (w), 2834 (w), 1599 (m), 1580 (s), 1563 (m), 1492 (s), 1459 (s), 1422 (s), 1300 (m), 1237 (s), 1160 (m), 1021 (s), 987 (m), 852 (w), 791 (m), 745 (s), 611 (m); MS (GC, 70 eV): *m/z* (%): 186 (M^++1, 9), 185 (M^+, 76), 184 (81), 156 (41), 155 (53), 154 (100), 141 (14), 128 (12), 127 (13), 115 (11), 89 (8), 80 (24), 78 (12), 51 (9); HRMS Pos (ESI) calcd for $C_{12}H_{12}NO$ $[M+H]^+$calcd is 186.0913 found 186.0916 and exact ion mass is 185.0841.

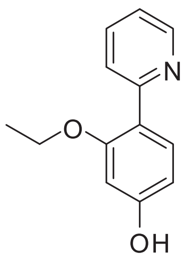
4-(Pyridin-2-yl)phenol (27b):



Chemical Formula: $C_{11}H_9NO$
Exact Mass: 171.07

Starting with 2-ethynyl pyridine **26** (103 mg, 1.0 mmol), diene **24** (505 mg, 3.0 mmol), MeOH (5 mL), K_2CO_3 (0.69g, 5 mmol), **27b** was isolated as colorless crystals (97 mg, 57%), m.p 151-153°C; ^{1}H NMR (300 MHz, DMSO-d_6): δ = 6.87 (td, *J* = 8.8, 1.9 Hz, 2H, ArH), 7.20-7.24 (m, 1H, ArH), 7.77-7.83 (m, 2H, ArH), 7.93 (td, *J* = 8.8, 1.9 Hz, 2H, ArH), 8.58 ($d_{(br)}$, *J* = 4.8 Hz, 1H, ArH), 9.73 ($s_{(br)}$, 1H, OH); ^{13}C NMR (75.46 MHz, DMSO-d_6): δ = 115.4 (2CH), 119.0 (CH), 121.4 (CH), 127.9 (2CH), 129.6 (C), 136.9 (CH), 149.2 (CH), 156.1 (C), 158.5 (C); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3180-2481 (b), 1592 (s), 1561 (m), 1523 (m), 1467 (s), 1422 (s), 1268 (s), 1246(s), 1181 (s), 1098 (m), 998 (s), 837 (s), 776 (s), 743 (s), 576 (m); MS (GC, 70 eV): *m/z* (%): 172 (M^++1, 11), 171 (M^+, 100), 170 (30), 154 (9), 142 (11), 117 (8), 115 (9), 63 (3), 39 (2); HRMS Pos (ESI) calcd for $C_{11}H_{10}NO$ $[M+H]^+$calcd is 172.0757 found 172.0756 and exact ion mass is 171.0684.

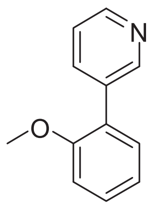
3-Ethoxy-4-(pyridin-2-yl)phenol (27c):



Chemical Formula: $C_{13}H_{13}NO_2$
Exact Mass: 215.09

Starting with 2-ethynyl pyridine **26** (103 mg, 1.0 mmol), diene **25** (636 mg, 3.0 mmol), MeOH (5 mL), K_2CO_3 (0.69 g, 5 mmol), **27c** was isolated as colorless crystals (118 mg, 55%), m.p 142-143°C; ^{1}H NMR (300 MHz, CDCl$_3$): δ = 1.21 (t, *J* = 7.0 Hz, 3H, CH$_3$), 3.66 (q, *J* = 7.0 Hz, 2H, OCH$_2$), 6.22-6.24 (m, 1H, ArH) , 6.26 (d, *J* = 2.2 Hz, 1H, ArH), 7.11 (dt, *J* = 6.2, 1.3 Hz, 1H, ArH), 7.37 (d, *J* = 8.1 Hz, 1H, ArH), 7.63 (dt, *J* = 8.0, 1.8 Hz, 1H, ArH), 7.71 (d, *J* = 7.9 Hz, 1H, ArH), 8.51-8.53 (m, 1H, ArH), 10.91 ($s_{(br)}$, 1H, OH); ^{13}C NMR (62.89 MHz, CDCl$_3$): δ = 14.6 (CH$_3$), 63.5 (OCH$_2$), 100.3 (CH), 108.2 (CH), 118.9 (C), 121.2 (CH), 125.5 (CH), 131.8 (CH), 136.5 (CH), 147.9 (CH), 156.4 (C), 157.4 (CH), 160.0 (C); IR (ATR, cm^{-1}): IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3220-2550 (b), 1613 (w), 1575 (s), 1454 (s), 1295 (m), 1180 (s), 1128 (s), 1035 (m), 991 (m), 774 (s), 632 (m), 563 (m); MS (GC, 70 eV): *m/z* (%): 216 (M^++1, 9), 215 (M^+, 63), 214 (55), 201 (13), 200 (92), 187 (12), 186 (55), 172 (23), 171 (100), 170 (23), 130 (31), 117 (12), 80 (11), 63 (7), 51 (5), 29 (4); HRMS (EI) calcd for $C_{13}H_{13}NO_2$ $[M^+]$: 215.09408, found 215.09396.

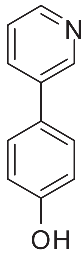
3-(2-Methoxyphenyl)pyridine (29a):



Chemical Formula: $C_{12}H_{11}NO$
Exact Mass: 185.08

Starting with 3-ethynyl pyridine **28** (206 mg, 2.0 mmol) and diene **23** (0.35 mL, 3.0 mmol), **29a** was isolated as colorless viscous liquid (192 mg, 52%); ^{1}H NMR (300 MHz, CDCl$_3$): δ = 3.72 (s, 3H, OCH$_3$), 6.92 (d, *J* = 8.3 Hz, 1H, ArH), 6.97 (dt, *J* = 7.5, 1.0 Hz, 1H, ArH), 7.21-7.31 (m, 3H, ArH), 7.77 (td, *J* = 8.0, 2.0 Hz, 1H, ArH), 8.47 (d, *J* = 3.7 Hz, 1H, ArH), 8.70 ($s_{(br)}$, 1H, ArH); ^{13}C NMR (62.89 MHz, CDCl$_3$): δ = 55.4 (OCH$_3$), 111.2 (CH), 120.9 (CH), 122.8 (CH), 126.9 (C), 129.4 (CH), 130.5 (CH), 134.1 (C), 136.6 (CH), 147.8 (CH), 150.2 (CH), 156.5 (C); IR (ATR, cm^{-1}): IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3025 (w), 2936 (w), 2833 (w), 1598 (w), 1496 (s), 1462 (s), 1405(s), 1333 (w), 1264 (s), 1235 (s), 1179 (m), 1121 (m), 1024 (s), 997 (s), 800 (m), 710 (s); MS (GC, 70 eV): *m/z* (%):186 (M^++1, 13), 185 (M^+, 100), 184 (10), 170 (49), 141 (5), 115 (23), 89 (5), 63 (4); HRMS (EI) calcd for $C_{12}H_{11}NO$ [M^+]: 185.08352, found 185.08289.

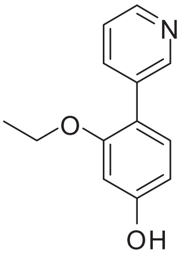
4-(Pyridin-3-yl)phenol (29b):



Chemical Formula: $C_{11}H_9NO$
Exact Mass: 171.07

Starting with 3-ethynyl pyridine **28** (103 mg, 1.0 mmol), diene **24** (505 mg, 3.0 mmol), MeOH (5 mL), K_2CO_3 (0.69g, 5 mmol), **29b** was isolated as colorless crystals (75 mg, 44%), m.p 198-199°C; ^{1}H NMR (300 MHz, DMSO-d_6): δ = 6.90 ($d_{(br)}$, *J* = 8.5 Hz, 2H, ArH), 7.39 (dd, *J* = 7.8, 4.8 Hz, 1H, ArH), 7.54 ($d_{(br)}$, *J* = 8.5 Hz, 2H, ArH), 7.94 ($d_{(br)}$, *J* = 8.1 Hz, 1H, ArH), 8.48 (d, *J* = 4.0 Hz, 1H, ArH), 8.82 (s, 1H), 9.71 ($s_{(br)}$, 1H, OH); ^{13}C NMR (75.46 MHz, DMSO-d_6): δ = 116.0 (2CH), 123.7 (CH), 127.7 (C), 128.0 (2CH), 133.2 (CH), 135.6 (C), 147.0 (CH), 147.4 (CH), 157.7 (C); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3170-2480 (b), 1698 (w), 1591 (m), 1580 (m), 1454 (m), 1385 (w), 1271 (m), 1232(m), 1176 (m), 1062 (m), 1022 (m), 840 (s), 809 (s), 697 (s), 549 (s); MS (GC, 70 eV): *m/z* (%): 172 (M^++1, 14), 171 (M^+, 100), 170 (19), 142 (10), 117 (12), 115 (11), 89 (5), 32 (4); HRMS Pos (ESI) calcd for $C_{11}H_{10}NO$ $[M+H]^+$calcd is 172.0757 found 172.0756 and exact ion mass is 171.0684.

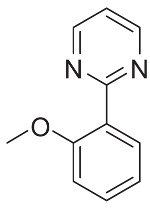
3-Ethoxy-4-(pyridin-3-yl)phenol (29c):



Chemical Formula: $C_{13}H_{13}NO_2$
Exact Mass: 215.09

Starting with 3-ethynyl pyridine **28** (103 mg, 1.0 mmol), diene **25** (636 mg, 3.0 mmol), MeOH (5 mL), K_2CO_3 (0.69 g, 5 mmol), **29c** was isolated as colorless crystals (90 mg, 42%), m.p 168-170°C; ^{1}H NMR (300 MHz, DMSO-d_6): δ = 1.27 (t, *J* = 6.9 Hz, 3H, CH_3), 4.01 (q, *J* = 6.9 Hz, 2H, OCH_2), 6.49 (dd, *J* = 8.2, 2.1 Hz, 1H, ArH), 6.54 (d, *J* = 2.0 Hz, ArH), 7.18 (d, *J* = 8.2 Hz, 1H, ArH), 7.40 (dd, *J* = 7.8, 4.8 Hz, 1H, ArH), 7.87 ($d_{(br)}$, *J* = 7.9 Hz, 1H, ArH), 8.45 (d, *J* = 3.7 Hz, 1H, ArH), 8.68 (s, 1H, ArH), 9.69 ($s_{(br)}$, 1H, OH); ^{13}C NMR (62.89 MHz, DMSO-d_6): δ = 14.6 (CH_3), 63.5 (OCH_2), 100.4 (CH), 108.0 (CH), 117.1 (C), 123.3 (CH), 131.1 (CH), 134.3 (C), 136.5 (CH), 146.7 (CH), 149.3 (CH), 156.7 (C), 159.1 (C); IR (ATR, cm^{-1}); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3110-2390 (b), 1598 (m), 1513 (w), 1453 (s), 1385 (m), 1301 (m),1257 (m), 1198 (s), 1120 (m), 1042 (m), 997 (m), 899 (w), 808 (s), 707 (s), 636 (s); MS (GC, 70 eV): *m/z* (%): 216 (M^++1, 14), 215 (M^+, 100), 187 (83), 186 (60), 160 (16), 158 (9), 131 (8), 130 (11), 77 (7), 51 (3); HRMS Pos (ESI) calcd for $C_{13}H_{14}NO_2$ $[M+H]^+$calcd is 216.1019 found 216.1018 and exact ion mass is 215.0946.

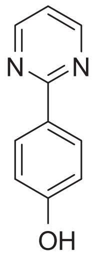
2-(2-Methoxyphenyl)pyrimidine (32a):



Chemical Formula: $C_{11}H_{10}N_2O$
Exact Mass: 186.08

Starting with 2-ethynyl pyrimidine **31** (208 mg, 2.0 mmol) and diene **23** (0.35 mL, 3.0 mmol) **32a** was isolated as yellowish viscous liquid (257 mg, 69%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.79 (s, 3H, OCH_3), 6.96 (d, *J* = 8.3 Hz, 1H, ArH) , 6.99 (dt, *J* = 7.5, 0.9 Hz, 1H, ArH), 7.13 (t, *J* = 4.9 Hz, 1H, ArH), 7.32-7.38 (m, 1H, ArH), 7.64 (dd, *J* = 7.5, 1.8 Hz, 1H, ArH), 8.77 (d, *J* = 4.9 Hz, 2H, ArH); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ = 56.0 (OCH_3), 111.9 (CH), 118.6 (CH), 120.7 (CH), 128.3 (C), 131.0 (CH), 131.7 (CH), 157.0 (2CH), 157.6 (C), 165.9 (C); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3033 (w), 2937 (w), 2834 (w), 1714 (w), 1600 (m), 1566 (s), 1552 (s), 1494 (m), 1460 (m), 1412 (s), 1275 (m), 1238 (s), 1179 (m), 1127 (m), 1057 (m), 1021 (s), 803 (m), 750 (s) , 633 (s); MS (GC, 70 eV): *m/z* (%):(%): 187 (M^++1, 12), 186 (M^+, 100), 185 (50), 169 (34), 158 (12), 157 (39), 156 (29), 155 (13), 130 (29), 104 (13), 103 (44), 90 (15); HRMS Pos (ESI) calcd for $C_{11}H_{11}N_2O$ $[M+H]^+$calcd is 187.0866 found 187.0866 and exact ion mass is 186.0793.

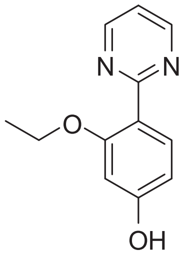
4-(Pyrimidin-2-yl)phenol (32b):



Chemical Formula: $C_{10}H_8N_2O$
Exact Mass: 172.06

Starting with 2-ethynyl pyrimidine **31** (104 mg, 1.0 mmol), diene **24** (505 mg, 3.0 mmol), MeOH (5 mL), K_2CO_3 (0.69 g, 5 mmol), **32b** was isolated as colorless crystals (107 mg, 62%), m.p 183-185°C; ^{1}H NMR (300 MHz, DMSO-d_6): δ = 6.89 (td, *J* = 8.8, 2.1 Hz, 2H, ArH), 7.31 (t, *J* = 4.9 Hz, 1H, ArH), 8.26 (td, *J* = 8.8, 2.1 Hz, 2H, ArH), 8.81 (d, *J* = 4.9 Hz, 2H, ArH), 9.97 ($s_{(br)}$, 1H, OH); ^{13}C NMR (62.89 MHz, DMSO-d_6): δ = 115.6 (2CH), 118.8 (CH), 128.3 (C), 129.6 (2CH), 157.6 (2CH), 160.2 (C), 163.6 (C); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3129-2354 (b), 1704 (w), 1609 (m), 1550 (s), 1519 (m), 1407 (s), 1317 (m), 1283 (s), 1204 (s), 1166 (s), 1100 (m), 993 (m), 783 (s), 646 (s), 630 (s); MS (GC, 70 eV): *m/z* (%): 173 (M^++1, 12), 172 (M^+, 100), 171 (12), 144 (2), 119 (55), 91 (4), 64 (5), 39 (2); HRMS (EI) calcd for $C_{10}H_8N_2O$ $[M^+]$: 172.06311, found 172.06280.

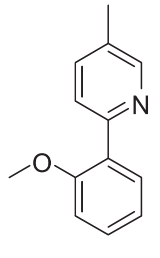
3-Ethoxy-4-(pyrimidin-2-yl)phenol (32c):



Chemical Formula: $C_{12}H_{12}N_2O_2$
Exact Mass: 216.09

Starting with 2-ethynyl pyrimidine **31** (104 mg, 1.0 mmol), diene **25** (636 mg, 3.0 mmol), MeOH (5 mL), K_2CO_3 (0.69 g, 5 mmol), **32c** was isolated as colorless crystals (134 mg, 62%), m.p 185-186°C; ^{1}H NMR (300 MHz, DMSO-d_6): δ = 1.25 (t, J = 6.9 Hz, 3H, CH_3), 4.00 (q, J = 6.9 Hz, 2H, OCH_2), 6.47 (dd, J = 8.3, 1.8 Hz, ArH), 6.51 (d, J = 1.5 Hz, ArH), 7.31 (t, J = 4.8 Hz, 1H, ArH), 7.49 (d, J = 8.3 Hz, 1H, ArH), 8.81 (d, J = 4.8 Hz, 2H, ArH), 9.81 ($s_{(br)}$, 1H, OH); ^{13}C NMR (62.89 MHz, DMSO-d_6): δ = 14.7 (CH_3), 64.0 (OCH_2), 101.1 (CH), 107.5 (CH), 118.5 (CH), 120.2 (C), 132.6 (CH), 157.0 (2CH), 158.4 (C), 160.1 (C), 165.4 (C); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3134-2606 (b), 1599 (m), 1571 (s), 1552 (s), 1468 (w), 1407 (s), 1321 (m), 1277 (s), 1235 (s), 1085 (m), 992 (m), 820 (m), 771 (m), 638 (s); MS (GC, 70 eV): *m/z* (%): 217 (M$^+$+1, 11), 216 (M$^+$, 100), 215 (26), 201 (42), 199 (13), 188 (15), 173 (18), 172 (74), 171 (11), 135 (18), 131 (25), 119 (29), 79 (6), 52 (6); HRMS (EI) calcd for $C_{12}H_{12}N_2O_2$ [M$^+$]: 216.08933, found 216.08890.

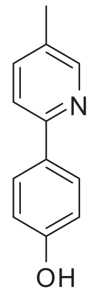
2-(2-Methoxyphenyl)-5-methylpyridine (35a):



Chemical Formula: $C_{13}H_{13}NO$
Exact Mass: 199.10

Starting with 2-ethynyl-5-methylpyridine **34** (234 mg, 2.0 mmol) and diene **23** (0.35 mL, 3.0 mmol), **35a** was isolated as colorless greenish viscous liquid (219 mg, 55%); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.28 (s, 3H, CH_3), 3.76 (s, 3H, OCH_3), 6.91 (d, J = 8.3 Hz, 1H, ArH), 7.00 (dt, J = 7.5, 1.0 Hz, 1H, ArH), 7.24-7.30 (m, 1H, ArH)), 7.42 (dd, J = 8.1, 2.2 Hz, 1H, ArH), 7.63 (d, J = 8.0 Hz, 1H, ArH), 7.68 (dd, J = 7.6, 1.8 Hz, 1H, ArH), 8.46 (s $_{(br)}$, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 18.0 (CH_3), 55.4 (OCH_3), 111.2 (CH), 120.8 (CH), 124.3 (CH), 129.0 (C), 129.4 (CH), 130.8 (CH), 130.9 (C), 136.0 (CH), 149.6 (CH), 153.2 (C), 156.7 (C); IR (ATR, cm^{-1}): IR (ATR, cm^{-1}): $\tilde{\nu}$ = 2997 (w), 2920 (w), 2834 (w), 1599 (m), 1581(m), 1495 (s), 1462 (s), 1434 (s), 1357 (m), 1240 (s), 1178 (m), 1121 (m), 1056 (m), 1022 (s), 832 (m), 750 (s); MS (GC, 70 eV): *m/z* (%): 200 (M$^+$+1, 13), 199 (M$^+$, 100), 198 (99), 170 (46), 169 (63), 168 (60), 167 (14), 154 (22), 142 (10), 141 (29), 128 (15), 115 (12), 94 (34), 84 (11). HRMS (EI) calcd for $C_{13}H_{13}NO$ [M$^+$]: 199.09973, found 199.09890.

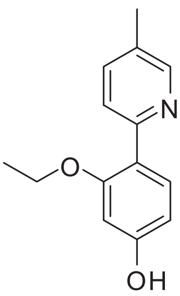
4-(5-Methylpyridin-2-yl)phenol (35b):



Chemical Formula: $C_{12}H_{11}NO$
Exact Mass: 185.08

Starting with 2-ethynyl-5-methylpyridine **34** (117 mg, 1.0 mmol), diene **24** (505 mg, 3.0 mmol), MeOH (5 mL), K_2CO_3 (0.69 g, 5 mmol), **35b** was isolated as colorless crystals (80 mg, 43%), m.p 173-175°C; ^{1}H NMR (300 MHz, DMSO-d_6): δ = 2.30 (s, 3H, CH_3), 6.85 (td, J = 8.8, 2.1 Hz, 2H, ArH), 7.61 (dd, J = 8.2, 2.2 Hz, 1H, ArH), 7.72 (d, J = 8.1 Hz, 1H, ArH), 7.90 (td, J = 8.8, 2.1 Hz, 2H, ArH), 8.42 ($s_{(br)}$, 1H, ArH), 9.67 ($s_{(br)}$, 1H, OH); ^{13}C NMR (62.89 MHz, DMSO-d_6): δ = 17.7 (CH_3), 115.5 (2CH), 118.6 (CH), 127.7 (2CH), 129.8 (C), 130.5 (C), 137.4 (CH), 149.6 (CH), 153.7 (C), 158.3 (C); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3080-2470 (b), 1704 (w), 1672 (w), 1601 (s), 1593 (s), 1522(w), 1472 (s), 1374 (m), 1266 (s), 1234 (s), 1176 (m), 1111 (m), 1043 (m), 819 (s), 759 (m), 651(m); MS (GC, 70 eV): *m/z* (%): 186 (M^++1, 14), 185 (M^+, 100), 184 (30), 157 (11), 141 (3), 131 (5), 128 (5), 63 (3), 39 (2); HRMS Pos (ESI) calcd for $C_{12}H_{12}NO$ $[M+H]^+$calcd is 186.0913 found 186.0913 and exact ion mass is 185.0841.

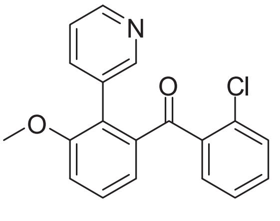
3-Ethoxy-4-(5-methylpyridin-2-yl)phenol (35c):



Chemical Formula: $C_{14}H_{15}NO_2$
Exact Mass: 229.11

Starting with 2-ethynyl-5-methylpyridine **34** (117 mg, 1.0 mmol), diene **25** (636 mg, 3.0 mmol), MeOH (5 mL), K_2CO_3 (0.69 g, 5 mmol), **35c** was isolated as colorless crystals (110 mg, 48%), m.p 189-191°C; ^{1}H NMR (300 MHz, DMSO-d_6): δ = 1.34 (t, J = 6.9 Hz, 3H, CH_3), 2.29 (s, 3H, CH_3), 4.04 (q, J = 6.9 Hz, 2H, OCH_2), 6.45-6.50 (m, 2H, ArH), 7.55 (dd, J = 8.2, 1.8 Hz, 1H, ArH), 7.66 (d, J = 8.3 Hz, 1H, ArH), 7.78 (d, J = 8.2 Hz, 1H, ArH), 8.42 (s, 1H, ArH), 9.66 ($s_{(br)}$, 1H, OH); ^{13}C NMR (62.89 MHz, DMSO-d_6): δ = 14.7 (CH_3), 17.7 (CH_3), 63.6 (OCH_2), 100.1 (CH), 107.8 (CH), 119.5 (C), 123.5 (CH), 130.0 (C), 131.5 (CH), 136.2 (CH), 149.3 (CH), 152.7 (C), 157.3 (C), 159.2 (C); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3120-2528 (b), 1613 (w), 1579 (m), 1455 (s), 1362 (w), 1300 (s), 1182 (s), 1124 (m), 1040 (s), 899 (w), 818 (s), 724 (w), 589 (m); MS (GC, 70 eV): *m/z* (%): 230 (M^++1, 6), 229 (M^+, 47), 228 (36), 214 (82), 200 (26), 186 (26), 185 (100), 184 (28), 144 (21), 115 (9), 94 (12), 65 (5), 32 (4); HRMS Pos (ESI) calcd for $C_{14}H_{16}NO_2$ $[M+H]^+$calcd is 230.1176 found 230.1178 and exact ion mass is 229.1103.

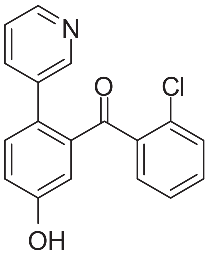
(2-Chlorophenyl)(3-methoxy-2-(pyridin-3-yl)phenyl)methanone (37a) :



Chemical Formula: $C_{19}H_{14}ClNO_2$
Exact Mass: 323.07

Starting with 1-(2-chlorophenyl)-3-(pyridin-3-yl)prop-2-yn-1-one **36** (121 mg, 0.5 mmol) and diene **23** (0.18 mL, 1.5 mmol), **37a** was isolated as brown viscous liquid (98 mg, 61 %); ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.70 (s, 3H, OCH_3), 6.89 (d, *J* = 7.7 Hz, 1H, ArH) , 6.95 (d, *J* = 8.2 Hz, 1H, ArH), 7.04-7.10 (m, 2H, ArH), 7.19-7.21 (m, 2H, ArH), 7.36 ($d_{(br)}$, *J* = 7.7 Hz, 1H, ArH), 7.42 (t, *J* = 8.1 Hz, 1H, ArH), 7.52 (td, *J* = 7.8, 1.9 Hz, 1H, ArH), 8.36 ($d_{(br)}$, *J* = 4.0 Hz, 1H, ArH), 8.41 (s, 1H, ArH); ^{13}C NMR (75.46 MHz, $CDCl_3$): δ = 56.0 (OCH_3), 111.0 (CH), 122.5 (CH), 122.7 (CH), 126.4 (CH), 129.6 (C), 130.9 (CH), 131.1 (CH), 131.6 (CH), 132.5 (CH), 132.9 (C), 135.4 (C), 136.3 (CH), 137.3 (C), 138.1 (C), 148.5 (CH), 149.3 (CH), 157.5 (C), 194.6 (CO); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3049 (w), 2937 (w), 2834 (w), 1600 (m), 1580 (s), 1492 (s), 1459 (s), 1422 (s), 1300 (m), 1256 (s), 1237 (s), 1179 (m), 1122 (m), 1021 (s), 987 (m), 745 (s), 729 (s), 611 (m); MS (GC, 70 eV): *m/z* (%): 325 (M^+, ^{37}Cl, 17), 323 (M^+, ^{35}Cl, 40), 322 (11), 294 (22), 289 (20), 288 (90), 272 (13), 260 (22), 213 (20), 212 (100), 207 (26), 183 (13), 169 (19), 141 (19), 139 (33), 111 (22), 75 (12); HRMS Pos (ESI) calcd for $C_{19}H_{15}ClNO_2$ [M+H, ^{35}Cl]$^+$calcd is 324.0786 found 324.0786 and exact ion mass is 323.0713.

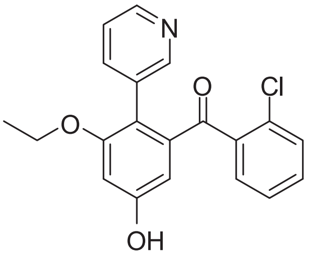
(2-Chlorophenyl)(5-hydroxy-2-(pyridin-3-yl)phenyl)methanone (37b):



Chemical Formula: $C_{18}H_{12}ClNO_2$
Exact Mass: 309.06

Starting with 1-(2-chlorophenyl)-3-(pyridin-3-yl)prop-2-yn-1-one **36** (121 mg, 0.5 mmol), diene **24** (252 mg, 1.5 mmol), MeOH (2.5 mL), K_2CO_3 (0.34g, 2.5 mmol), **37b** was isolated as colorless crystals (79 mg, 51%), m.p 98-100°C; ^{1}H NMR (300 MHz, DMSO-d_6): δ = 6.79 (d, *J* = 2.4 Hz, 1H, ArH) , 6.93 (dd, *J* = 8.5, 2.4 Hz, 1H, ArH), 7.28-7.41 (m, 5H, ArH), 7.45 (d, *J* = 8.5 Hz, 1H, ArH), 7.65 ($td_{(br)}$, *J* = 8.0, 1.9 Hz, 1H, ArH), 8.42-8.44 (m, 2H, ArH), 10.67 ($s_{(br)}$, 1H, OH); ^{13}C NMR (75.46 MHz, DMSO-d_6): δ = 114.8 (CH), 118.3 (CH), 122.9 (CH), 127.0 (CH), 128.1 (C), 129.9 (CH), 130.1 (CH), 130.3 (C), 131.8 (CH), 134.1 (CH), 135.7 (CH), 136.3 (C), 138.8 (C), 141.5 (C), 148.0 (CH), 148.5 (CH), 161.1 (C), 193.9 (CO); IR (ATR, cm^{-1}): $\tilde{\nu}$ = 3143-2425 (b), 1651 (w), 1587 (m), 1462 (w), 1291 (s), 1218 (s), 1124 (m), 1053 (w), 929 (m), 758 (s), 710 (s), 605 (s); MS (GC, 70 eV): *m/z* (%): 311 (M^+, ^{37}Cl, 9), 310 (M^++1, ^{35}Cl, 13), 309 (M^+, ^{35}Cl, 29), 308 (26), 280 (23), 274 (52), 246 (15), 207 (18), 199 (66), 198 (100), 139 (18), 115 (14), 111 (13), 44 (6); HRMS (EI) calcd for $C_{18}H_{12}NO_2Cl$ [M^+, ^{35}Cl]: 309.05511, found 309.05438.

(2-Chlorophenyl)(3-ethoxy-5-hydroxy-2-(pyridin-3-yl)phenyl)methanone (37c):



Chemical Formula: $C_{20}H_{16}ClNO_3$
Exact Mass: 353.08

Starting with 1-(2-chlorophenyl)-3-(pyridin-3-yl)prop-2-yn-1-one **36** (121 mg, 0.5 mmol), diene **25** (318 mg, 1.5 mmol), MeOH (2.5 mL), K_2CO_3 (0.34g, 2.5 mmol), **37c** was isolated as colorless crystals (97 mg, 55%), m.p = (154-56°C); ^{1}H NMR (300 MHz, DMSO-d_6): δ = 0.82 (t, J = 6.9 Hz, 3H, CH_3), 3.82 (q, J = 6.9 Hz, 2H, OCH_2), 6.40 (d, J = 2.1 Hz, 1H, ArH) , 6.50 (d, J = 2.0 Hz, 1H, ArH), 7.32-7.50 (m, 5H, ArH), 7.66 (td$_{(br)}$, J = 7.9, 2.0 Hz, 1H, ArH), 8.45 (d, J = 1.8 Hz, 1H, ArH), 8.47 (dd, J = 4.8, 1.4 Hz, 1H, ArH), 10.37 (s$_{(br)}$, 1H, OH); ^{13}C NMR (62.89 MHz, DMSO-d_6): δ = 13.9 (CH_3), 63.9 (OCH_2), 99.7 (CH), 110.4 (CH), 120.0 (C), 123.2 (CH), 127.2 (CH), 130.3 (CH), 130.4 (CH), 131.1 (C), 132.2 (CH), 135.9 (CH), 136.4 (C), 140.0 (C), 140.7 (C), 148.2 (CH), 148.7 (CH), 159.5 (C), 160.9 (C), 193.6 (CO); IR (ATR, cm^{-1}): $\widetilde{\nu}$ = 3151-2580 (b), 1667 (m), 1558 (m), 1435 (m), 1291 (m), 1178 (s), 1137 (m), 1035 (s), 928 (m), 762 (s), 742 (s), 623 (s); MS (GC, 70 eV): m/z (%): 355 (M^+, ^{37}Cl, 5), 354 (M^++1, ^{35}Cl, 10), 353 (M^+, ^{35}Cl, 24), 308 (42), 242 (18), 214 (100), 199 (32), 198 (43), 139 (3), 115 (94), 111 (7), 44 (21); HRMS Pos (ESI) calcd for $C_{20}H_{17}ClNO_3$ [M+H, $^{35}Cl]^+$calcd is 354.0894 found 354.0891 and exact ion mass is 353.0819.

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X-Ray Crystals Data

Data for compound 6h Chapter 1:

Identification code	6h	
Empirical formula	$C_{19}H_{17}ClFNO_4$	
Formula weight	377.79	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	P21/n	
Space group (Hall)	-P 2yn	
Unit cell dimensions	a = 10.0412 (3) Å	α= 90°.
	b = 8.9336 (2) Å	β=102.052 (1)°.
	c = 21.0207 (5) Å	γ = 90°.
Volume	1844.08 (8) Å^{3}	
Z	4	
Density (calculated)	1.361 Mg/m^{3}	
Absorption coefficient	0.240 mm^{-1}	
F(000)	784	
Crystal size	0.36 × 0.35 × 0.32 mm^{3}	
Θ range for data collection	4.956 to 64.927 ° .	
Index ranges	-14≤h≤12, -8≤k≤12, -29≤l≤29	
Reflections collected	21688	
Independent reflections	5365 [R(int) = 0.0194]	
Completeness to Θ = 30.00°	99.8%	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.9270 and 0.9185	
Refinement method	Full-matrix least-squares on F^{2}	
Data / restraints / parameters	4494 / 0 / 241	
Goodness-of-fit on F^{2}	1.083	
Final R indices [I>2σ(I)]	R1 = 0.0343, wR2 = 0.0951	
R indices (all data)	R1 = 0.0432, wR2 = 0.1000	
Largest diff. peak and hole	0.383 and -0.311 e.Å^{-3}	

Data for compound 11c Chapter 2:

Identification code	11c	
Empirical formula	$C_{26}H_{19}F_3O_7S$	
Formula weight	532.47	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	triclinic	
Space group (H.-M.)	P -1	
Space group (Hall)	-P 1	
Unit cell dimensions	a = 10.480 (8) Å	α= 70.109 (15) °.
	b = 14.421 (10) Å	β=80.04 (2) °.
	c = 17.478 (12) Å	γ = 73.38 (3) °.
Volume	2372 (3) $Å^3$	
Z	4	
Density (calculated)	1.491Mg/m^3	
Absorption coefficient	0.207 mm^{-1}	
F(000)	1096	
Crystal size	0.99 × 0.28 × 0.26mm^3	
Θ range for data collection	1.24 to 30.00 ° .	
Index ranges	$-14 \le h \le 14$, $-20 \le k \le 20$, $-24 \le l \le 23$	
Reflections collected	41364	
Independent reflections	13680 [R(int) = 0.0439]	
Completeness to Θ = 28.49°	98.2%	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.9483 and 0.8216	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	9788 / 2 / 775	
Goodness-of-fit on F^2	1.059	
Final R indices [$I>2\sigma(I)$]	R1 = 0.0483, wR2 = 0.1300	
R indices (all data)	R1 = 0.0751, wR2 = 0.1439	
Largest diff. peak and hole	0.273 and -0.223 e.$Å^{-3}$	

Data for compound 12a Chapter 2:

Identification code	12a	
Empirical formula	$C_{32}H_{23}F_3O_4$	
Formula weight	528.50	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	triclinic	
Space group (H.-M.)	P -1	
Space group (Hall)	-P 1	
Unit cell dimensions	a = 9.3439 (19) Å	α= 78.10 (3) °.
	b = 10.390 (2) Å	β= 83.88 (3) °.
	c = 13.867 (3) Å	γ = 75.39 (3) °.
Volume	1272.6 (4) Å^3	
Z	2	
Density (calculated)	1.379Mg/m^3	
Absorption coefficient	0.105 mm^{-1}	
F(000)	548	
Crystal size	0.65 × 0.20 × 0.09mm3	
Θ range for data collection	2.64 to 28.49 ° .	
Index ranges	-12≤h≤12, -13≤k≤13, -18≤l≤18	
Reflections collected	17379	
Independent reflections	6338 [R(int) = 0.0423]	
Completeness to Θ = 28.49°	98.2%	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.9906 and 0.9350	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	8374 / 0 / 396	
Goodness-of-fit on F^2	1.047	
Final R indices [I>2σ(I)]	R1 = 0.0561, wR2 = 0.1435	
R indices (all data)	R1 = 0.1027, wR2 = 0.1586	
Largest diff. peak and hole	0.273 and -0.223 e.Å^{-3}	

Data for compound 22a Chapter 3:

Identification code	22a	
Empirical formula	$C_{25}H_{20}ClF_3O_4$	
Formula weight	476.86	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	triclinic	
Space group (H.-M.)	P -1	
Space group (Hall)	-P 1	
Unit cell dimensions	a = 10.880 (6) Å	α= 97.036 (12) °.
	b = 14.622 (7) Å	β= 103.015 (11) °.
	c = 15.538 (6) Å	γ = 109.287 (12) °.
Volume	2220.5 (19) $Å^3$	
Z	4	
Density (calculated)	1.426Mg/m^3	
Absorption coefficient	0.23 mm^{-1}	
F(000)	984	
Crystal size	0.32 × 0.28 × 0.09 mm^3	
Θ range for data collection	1.38 to 27.50 ° .	
Index ranges	$-14\leq h\leq 14$, $-18\leq k\leq 16$, $-19\leq l\leq 20$	
Reflections collected	39515	
Independent reflections	10118 [R(int) = 0.0389]	
Completeness to Θ = 27.50°	99.3%	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.9798 and 0.9308	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	7499 / 0 / 625	
Goodness-of-fit on F^2	1.090	
Final R indices [$I>2\sigma(I)$]	R1 = 0.0492, wR2 = 0.1358	
R indices (all data)	R1 = 0. 0719, wR2 = 0.1461	
Largest diff. peak and hole	0.487 and -0.439 e.$Å^{-3}$	

Data for compound 27c Chapter 4:

Identification code	27c	
Empirical formula	C13H13NO2	
Formula weight	215.24	
Temperature	173(2) K	
Wavelength	0.71073Å	
Crystal system	Monoclinic	
Space group (H.-M.)	P21/n	
Space group (Hall)	-P 2yn	
Unit cell dimensions	a = 17.0143 (6) Å	α= 90°.
	b = 7.9005 (3)Å	β=110.692 (2)°.
	c = 17.9951 (7)Å	γ = 90°.
Volume	2262.89 (15)Å^3	
Z	8	
Density (calculated)	1.264 Mg/m^3	
Absorption coefficient	0.086 mm^{-1}	
F(000)	912	
Crystal size	0.68 × 0.20 × 0.14 mm^3	
Θ range for data collection	2.42 to 29.99° .	
Index ranges	$-23 \leq h \leq 23$, $-9 \leq k \leq 11$, $-25 \leq l \leq 22$	
Reflections collected	24034	
Independent reflections	6570 [R(int) = 0.0364]	
Completeness to Θ = 29.99°	99.6 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.988 and 0.944	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4516 / 0 / 299	
Goodness-of-fit on F^2	1.041	
Final R indices [$I>2\sigma(I)$]	R1 = 0.0441, wR2 = 0.1054	
R indices (all data)	R1 = 0.0753, wR2 = 0.1148	
Largest diff. peak and hole	0.276 and -0.276 e.Å^{-3}	

Declaration/Erklärung

Here by I declare that this work has so far neither submitted to the Faculty of Mathematics and Natural Sciences at the University of Rostock nor to any other scientific Institution for the purpose of doctorate. Further more, I declare that I have written this work by myself and that I have not used any other sources, other than mentioned earlier in this work.

Hiermit erkläre ich, daß diese Arbeit bisher von mir weder an der Mathematisch-Naturwissenschaftlichen Fakultät der Universität Rostock noch einer anderen wissenschaftlichen Einrichtung zum Zwecke der Promotion eingereicht wurde.

Ferner erkläre ich, dass ich diese Arbeit selbständig verfasst und keine anderen als die darin angegebenen Hilfsmittel benutzt habe

I hereby apply irrevocably to take oral examination in the form of a private viva voce and a public presentation.

Obaid-ur-Rahman Abid