UNIVERSITÄT ROSTOCK

Synthesis of 3-Aryl-3,4-dihydroisocoumarins and Sterically Encumbered Biaryls by [3+3] Cyclocondensation Reactions and Synthesis of Functionalized Fluoranthenes, Trifluoromethyl-Substituted Di- and Terphenyls and Tetraaryl-*p*-benzoquinones by Pd(0)-Catalysed Cross-Coupling Reactions

Dissertation

zur

Erlangung des Doktorgrades

doctor rerum naturalium (Dr. rer. nat.)

der Mathematisch-Naturwissenschaftlichen Fakultät

der Universität Rostock

vorgelegt von

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Rostock, April - 2011

urn:nbn:de:gbv:28-diss2011-0189-5

Die vorliegende Arbeit entstand in der Zeit von April 2008 bis März 2011 am Institut für Chemie der Universität Rostock.

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Einreichen der Arbeit:	28.4.2011
Rigorosum:	16.11.2011
Prüfer Hauptfach:	Prof. Dr. Dr. h.c. Peter Langer (Institut für Chemie, Universität Rostock)
Prüfer Nebenfach:	Prof. Dr. Reinhard Schröder (Institut für Biowissenschaften, Universität Rostock)
Tag der Verteidigung:	6.12.2011

Affectionately Dedicated to

My dear PARENTS

Acknowledgements

*In the name of **Allah**, Who is Ubiquitous, Omniscient, Worthy of all praise and Creator of all of us, Who guides in darkness and helps in difficulties. I do obeisance in thanks and gratitude for all His blessings, due to which I was able to accomplish this strenuous task.*

*All respect for the **Holy prophet Hazrat Muhammad** (Peace be upon Him), for enlightening our conscious with the essence of faith in Almighty **Allah** and also for prophesying the code of life **(The Holy Quran)**.*

*I would like to express my sincere gratitude and appreciation to my supervisor, **Professor Dr. Peter Langer** for his guidance, support and patience throughout the completion of my work. His enthusiasm in organic chemistry and advices have always encouraged me to study and investigate. I am really lucky to get chance of working with him.*

Sincere acknowledgments are made to Higher Education Commission (HEC) of Pakistan for financial support throughout my Ph.D.

My sincere appreciations are extended to my friends Muhammad nawaz, Mukhtharullah, Muhammad Sher, Asad Ali, Hameed ullah wazir, Tauseef Asmat for providing me moral support and enjoyable company during this period.

I am thankful to all my past and present colleagues, Noor ul Amin, Gul Wali khan, Niaz Ali, Izzat Khan, Muhammad Adeel, Imran Malik, Zahid Hasan, Rasheed Ahamd, Mohanad Shkoor, Olumide Fatunsin, Iftikhar Ali, Muhammad Zahid, Muhammad Sharif, Sajid Ali, Tariq Mahmood Babar, Obaid-ur-Rahman, Farooq Ibad, Dhafer Zinad, Ahmad Mahal for their support, encouragement and help to pursue this work and all others whom I have missed here do deserve equal credit.

I would also like to thank Friedrich Erben, Sebastain Reimann, Alina Bunescu, Dennis Kleeblat, Ingo Knepper, Franziska, Peter Ehlers, Stefen Büttner, Mathias Lau and all the other German colleagues. They always were willing to help me whenever I was need of them.

Thanks also go to Dr. Martin Hein, Dr. Alexander Villinger and all members of technical sections (NMR, IR, MS, EA and X-Ray etc) of Rostock University.

Last, but not least I'd like to thank technical & non-technical staff of the Institute of Chemistry, especially Anna Hallmann and Claudia Vinke for their tremendous support during my stay.

The most important is, to say that I have a great debt on my life due to the enormous sacrifices of my parents, brothers and sisters for their divine love, prayers, constant care, encouragement and continuous support throughout my studies. Whatever, I am, that is because of the countless prayers of my parents, who instilled in me, a charm for education and the value of being organized.

IHSAN ULLAH

April 2011, Rostock,

Germany.

MAIN CONTENTS

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General Introduction

Nature is one of the greatest sources of diverse small molecules with a broad bioactivity profile. Natural products continue to play an important role in the discovery and development of new pharmaceuticals, as clinically useful drugs, as starting materials to produce synthetic drugs, or as lead structures from which a synthetic drug can be designed.[1] A well known example is menthol which is extracted from the essential oil of spearmint. Natural products often represent important lead structures for the development of antibiotics.[2] In fact, a number of natural products exhibit antibiotic activity and since the discovery of penicillin, a large number of antibiotics have been isolated from a number of micro-organisms.[3] This discovery of new important anti-infective compounds include both plant and animal sources. For example, astemisinin, a sesquiterpene with endoperoxide moiety, was isolated from *Astemisia annua*, a Chinese medicinal plant, which has been used in China for centuries for treatment of malaria. The development of new drugs include synthetic and semi-synthetic studies, microbial transformations, the biological screening and the study of the mechanism of action.[4]

Many natural products have also provided important success in the chemotherapy of cancer diseases and a number of anticancer drugs represent unmodified natural products isolated from plants or micro-organisms:[5] For example, ironotecan, which is a camptothecin derivative, is a semi-synthetic derivative of natural products.

The structures of small compounds from nature have been optimized by evolution, and many of them have been tailored to interact with larger biomolecules to produce better physiological response. However, active natural products are not equipped with advanced biological properties required for a chemotherapeutic agent (e.g., toxicity issues). Moreover, a major limitation of screening natural products is their limited availability and tedious job of isolation.[6] Therefore, a series of skeletal and stereochemical analogues have to be developed synthetically and thus synthetic small molecules constitute a major portion of the modern screening palette. Advances in the field of synthetic organic chemistry have led to the development of many methodologies for efficient assembly of small molecules. Millions of organic compounds have been synthesized and many methods have been developed to access more and more complex chemical structures.

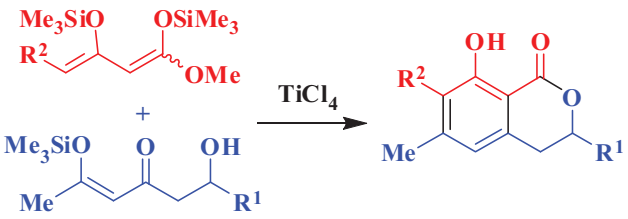
The ability to make target molecules with step economy, efficiency, selectivity, and in an environmentally safe and operationally simple fashion is an objective of great importance. The design or discovery of new reactions is a key to realize this aim and to realize practical syntheses of important targets.

The development of new methods for carbon-carbon and carbon-heteroatom bond formation is a prime topic in organic chemistry. In the past three decades, tremendous effort has been devoted into the transition-metal catalyzed cross-coupling reactions,[7] which permit the formation of carbon-carbon or carbon-heteroatom bonds in a way that is not accessible through traditional methods. Particularly in the last ten years, transition metal catalyzed processes have been developed which combine economy, efficiency, and elegance.[8] The application of transition-metal complexes as homogeneous catalysts has led to the development of simple and efficient methods of carbon-carbon and carbon-heteroatom bond formation.[9]

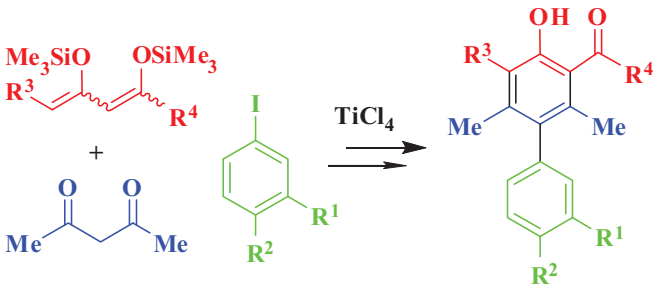
My studies are focused on the development of new and reliable synthetic strategies and their application to the preparation of natural product analogues and of pharmacologically active carba- and heterocycles. In the present thesis, the synthesis of natural product analogues is studied based on $TiCl_4$-mediated [3+3] cyclocondensation and Pd(0)-catalyzed reactions. The synthesized products include functionalized dihydroisocoumarins, sterically encumbered biaryls, functionalized fluoranthenes, trifluoromethyl-substituted di- and terphenyls and tetraaryl-*p*-benzoquinones.

The following paragraph outlines the tasks of this thesis. More details are given in the respective chapters about the synthesized products and the synthetic strategies. This thesis can be summarized as follows:

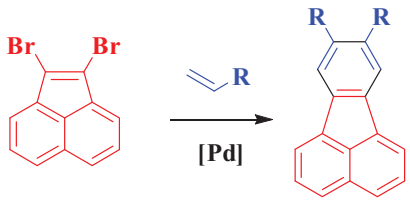
Synthesis of 3-aryl-3,4-dihydroisocoumarins by regioselective domino '[3+3] cyclization / lactonization' reactions of 1,3-bis-(silyloxy)-1,3-butadienes with 1-hydroxy-5-silyloxy-4-en-3-ones. This chapter includes the synthesis of 3-aryl-3,4-dihydroisocoumarins (3-arylisochroman-1-ones) by regioselective domino '[3+3] cyclization/lactonization' reactions of 1,3-bis(silyloxy)-1,3-butadienes **4** with 1-hydroxy-5-silyloxy-4-en-3-ones. 3-A ryl-3,4-dihydroisocoumarins are of considerable pharmacological relevance and occur in many natural products.



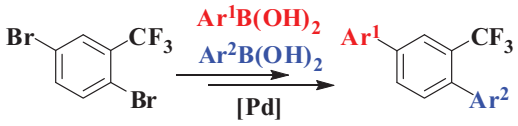
Synthesis of sterically encumbered biaryls based on a copper(I)-catalyzed arylation / [3+3] cyclocondensation' strategy. This chapter includes the synthesis of sterically encumbered biaryls which are prepared in two steps by CuI-proline-catalyzed arylation of acetylacetone to give 3 arylpentane-2,4-diones and subsequent formal [3+3] cyclization of the latter with 1,3-bis(trimethylsilyloxy)-1,3-dienes.



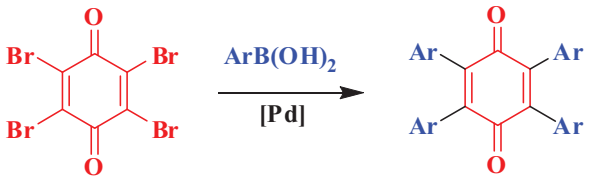
Synthesis of 8,9-disubstituted fluoranthenes by domino twofold Heck / electrocyclization / dehydrogenation of 1,2-dibromoacenaphthylene. This chapter deals with the palladium(0)-catalyzed Heck cross-coupling reactions of 1,2-dibromoacenaphthylene providing functionalized fluoranthenes by a domino ′twofold Heck / 6π-electrocyclization/dehydrogenation reaction.



Synthesis of trifluoromethyl-substituted di- and terphenyls by site-selective Suzuki-Miyaura reactions of 1,4-dibromo-2-(trifluoromethyl)benzene. This chapter deals with the Suzuki-Miyaura cross-coupling reactions of 1,4-dibromo-2-(trifluoromethyl)benzene with different arylboronic acids to give mono- and diaryl 2-(trifluoromethyl)benzenes with excellent site-selectivity. The first attack occurred at the more electronically deficient and sterically less hindered position C-4.



Synthesis of tetraaryl-p-benzoquinones by Suzuki sross-coupling reactions of tetrabromo-p-benzoquinone. This chapter includes Suzuki-Miyaura cross-coupling reactions of tetrabromo-1,4-benzoquinone with different arylboronic acids to give tetraaryl-1,4-benzoquinones in excellent yields.



A significant part of this dissertation has been published (see list of publications). A detailed introduction is given at the beginning of each individual chapter.

Chelation-control in the formal [3+3] cyclization of 1,3-bis(silyloxy)-1,3-butadienes with 1-hydroxy-5-silyloxyhex-4-en-3-ones. One-pot synthesis of 3-aryl-3,4-dihydroisocoumarins

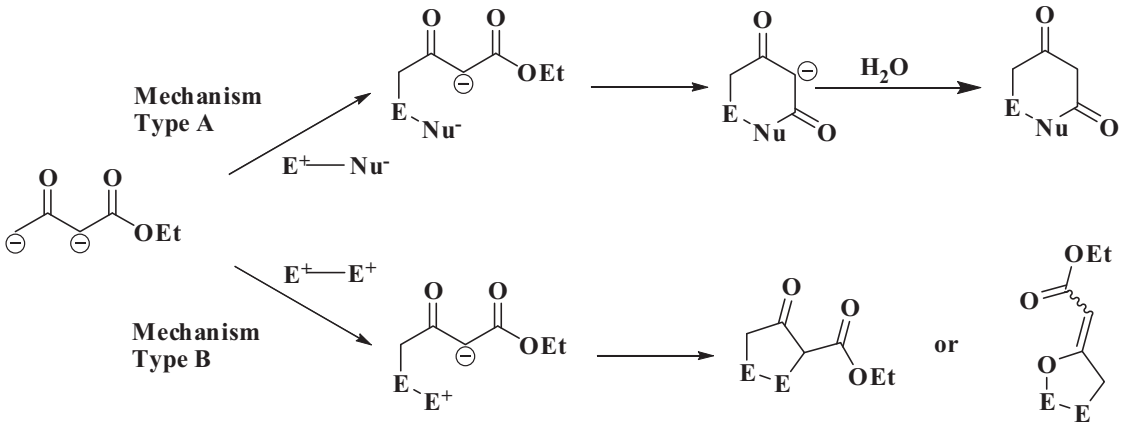
1.1 Synthesis of 1,3-bis(trimethylsilyloxy)buta-1,3-dienes

1.1.1 Introduction

The desire of organic chemists is to develop one-pot reactions to carry out a reaction in a single step without isolating intermediates. This approach will save costs, reduce the amounts of solvents, time and energy.

One-pot and domino reactions[10] include cyclization reactions of dielectrophiles with dinucleophiles and constitute important concepts for the formation of more than one bond in a single step. Thus, complex transformations have been made possible. The group of Prof. Langer has focussed on the development of cyclization reactions of dianions[11] and dianion equivalents leading to various biologically relevant ring systems. The reactions of dielectrophiles with dinucleophiles may seem simple, but many side reactions can occur.

However, dianions represent important building blocks for the regioselective formation of carbon–carbon bonds. Ambident dianions are organic substrates containing two delocalized negative charges. Dianions can be generated by reaction of 1,3-dicarbonyl compounds in the presence of strong base, such as *n*-BuLi or LDA.[12] The functionalization of the terminal carbon atom of the dianion can be done regioselectively with one equivalent of an electrophile E^+ to give a monoanion which can be subsequently trapped by addition of a second electrophile which represents an important synthetic method which has been used in the synthesis of natural products. Two general mechanistic pathways for cyclization reactions of dianions can be discussed as follows[12a] (Scheme **1.1**):



Scheme 1.1: Possible mechanistic pathways for cyclization reactions of 1,3-dicarbonyl dianions. Nu = nucleophilic center, E = electrophilic center

Mechanism type A: the dianion can react with monofunctional electrophiles with transposition of a negative charge from the dianion to the electrophile. This carbanion attacks an E^+ centre of the former dianion moiety (e.g. the ester group) to give a cyclic monoanion which is subsequently quenched with water.

Mechanism type B: the dianion can react as a dinucleophile with a dielectrophile. A monoanion is formed, followed by attack of the latter onto a second E^+ center.

Cyclization reactions of dianions with dielectrophiles are synthetically useful. However, problems can arise since both starting materials are highly reactive compounds which have low reactivity matching. In addition, 1,2- and 1,3-dielectrophiles are often rather labile, and reactions with nucleophiles can result in polymerization, decomposition, formation of open-chained products, elimination or SET-process. These intrinsic limitations can be overcome by two ways: a) a proper tuning of the reactivity of dianion and dieletrophile and b) the use of eletroneutral dianion equivalents (masked dianions) in Lewis acid catalyzed reactions.[12a]

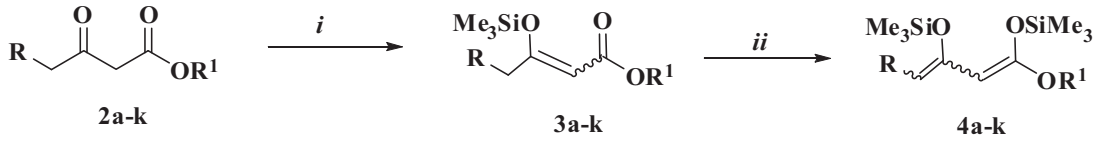
Recent studies proved that 1,3-bis(silyl enol ethers) can be considered as equivalents of the corresponding 1,3-dicarbonyl dianions.[13] The chemistry of 1,3-bis(silyl enol ethers) has been developed during the last two decades.[13b] It is, for example, known that silyl enol ethers can combine with various carbonyl compounds in the presence of Lewis acids.[14] These Lewis acid-mediated reactions[15] (e. g. alkylation and aldol condensation) provide useful alternatives to classical enolate chemistry. In cyclization reactions, 1,3-bis(silyl enol ethers) can react as 1,3-dinucleophiles or, similar to the well-known Danishefsky diene,[16] as functionalized butadienes.

1,3-Bis(silyl enol ethers) undergo reactions with electrophiles at the terminal carbon atom, followed by reaction of the central carbon or the oxygen atom. Enol silyl ethers can be cleaved with nucleophiles such as MeLi, $LiNH_2$ or $R_4N^+F^-$ to give enolates. They can be reacted with halides (Br_2, Cl_2, I_2) or pseudohalides (PhSCl, PhSeCl, Cl-N=O).[17] Whereas enolates can be alkylated only by primary or secondary halides, enol silyl ethers can be alkylated by tertiary halides.[18]

The preparation of 1,3-bis(silyl enol ethers) mainly follows the procedures reported by Chan and Molander. These syntheses rely on the preparation of 1,3-mono(silyl enol ethers) which are subsequently transformed into 1,3-bis(silyl enol ethers) by deprotonation with LDA and subsequent silylation.[19] In this section, I present the synthesis of various known 1,3-bis(silyl enol ethers), used in my thesis, following the procedure of Chan and Molander.

1.1.2 Results and Discussion

With the use of the procedures of Chan and Molander, 1,3-bis(trimethylsilyloxy)-1,3-butadienes **4a-k** were prepared from the respective 1,3-dicarbonyl compounds **2a-k** in two steps. Treatment of the β-ketoesters with NEt_3, Me_3SiCl afforded 1,3-mono(silyl enol ethers) **3a-k**. Deprotonation of the latter with LDA and subsequent addition of Me_3SiCl afforded the diene **4a-k** (Scheme **1.2**, Table **1.1**). Simchen *et al*. reported that 1,3-diketone derived bis-silyl enol ethers can be prepared in one step by treatment of an ether solution of the diketone with NEt_3 and Me_3SiOTf (2.0 equivalent).[13]

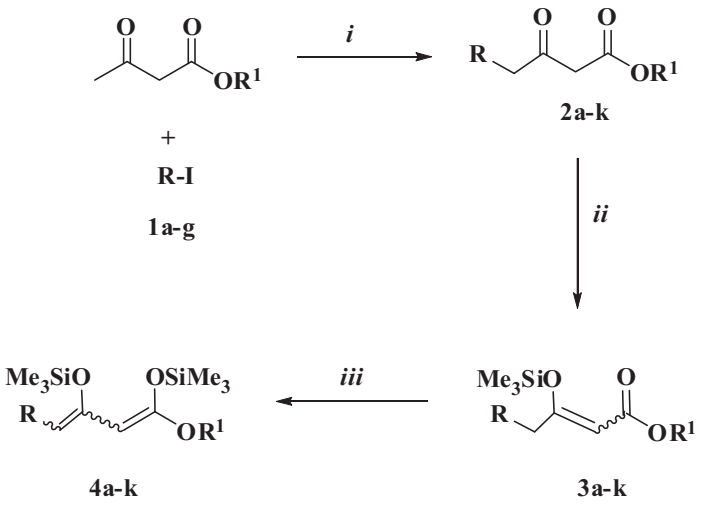


2a-k **3a-k** **4a-k**

Scheme 1.2: Synthesis of 1,3-bis(silyl enol ethers) **4a-k**; *i*) 1) NEt_3 (1.5 equiv.); 2) Me_3SiCl (1.5 equiv.), C_6H_6, 20 °C, 12 - 48 h; *ii*) 1) LDA (1.5 equiv.), THF, 0 °C, 2 h; 2) Me_3SiCl (1.5 equiv.), -78 → 20 °C, 6 - 12 h.

The synthesis of alkyl-substituted 1,3-bis(silyl enol ethers) requires the synthesis of the respective β-ketoesters **2a-k**. It is known that the regioselectivities of the reactions of monoanions and dianions generally differ greatly. 1,3-Dicarbonyl monoanions are generally alkylated at the central carbon or at the oxygen atom, whereas the formation of dianions allows the

functionalization of the terminal carbon atom. Based on this, the 4-alkyl-3-oxobutanoates **2a-k** were prepared by reactions of the dianion of methyl acetoacetate with the respective alkyl iodides **1a-g** (RI). These compounds were transformed, according to a known procedure,[15] into the desired 1,3-bis(silyl enol ethers) **4a-k** via the respective mono(silyl enol ethers) **3a-k** (Scheme **1.3**, Table **1.1**).



Scheme 1.3: Synthesis of alkyl-substituted 1,3-bis(silyl enol ethers) derivatives **4d-j**; *i*: 1) 2.5 LDA, THF, 0 °C, 1 h; 2) **1a-g** -78 → 20 °C; *ii*: Me_3SiCl (1.5 equiv.), NEt_3 (1.5 equiv.), C_6H_6, 20 °C, 48 h; *iii*: 1) LDA (1.5 equiv.), THF, –78 °C, 1 h; 2) Me_3SiCl (1.5 equiv.), 20 °C, –78 → 20 °C.

The prepared 4-alkyl-1,3-bis(silyl enol ethers) could be stored at suitable conditions (-20 ^{o}C, dry, inert gas atmosphere) for several months without decomposition. The 1,3-bis(silyl enol ethers) **4** of β-ketoesters used in this thesis are listed in the following table.

Table 1.1: 1,3-Bis(silyl enol ethers) **4a-k**

4	*R*	R^1
a	H	Me
b	H	Et
c	H	Bn
d	Me	Me
e	Me	Et
f	Et	Me
g	*n*Hex	Me
h	*n*Non	Me
i	CH_2=CH$(CH_2)_2$	Me
j	$C_6H_5(CH_2)_2$	Me
k	Cl	Me

1.1.3 Conclusion

The application of a known procedure allowed the synthesis of novel 4-alkyl-1,3-bis(silyl enol ethers). These masked dianions are used in the cyclization reactions for the synthesis of heterocycles and aromatic rings which represent important building blocks and natural product analogues.

1.2 Chelation-control in the formal [3+3] cyclization of 1,3-bis(silyloxy)-1,3-butadienes with 1-hydroxy-5-silyloxy-hex-4-en-3-ones. One-pot synthesis of 3-aryl-3,4-dihydroisocoumarins

1.2.1 Introduction

Dihydroisocoumarins, similar to isocoumarins and coumarins, are a class of naturally occurring lactones of a wide variety of microbial, plant and insect sources, exhibiting various biological activities.[20] Structurally, most of these natural products possess an aryl or alkyl substituent at C-3 and a hydroxy group at C-8 of the isocoumarin core. In addition, most of them are optically active due to the stereocenter at C-3 (Fig. **1.1**).

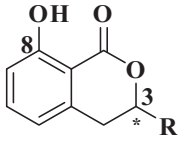
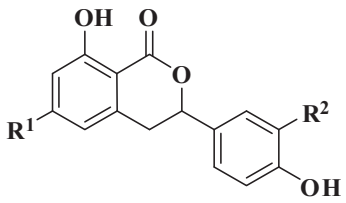


Figure: 1.1

3-Aryl-3,4-dihydroisocoumarins (3-aryl-isochroman-1-ones) have shown an impressive array of pharmacological activities and occur in several natural products. This includes, for example, thunberginol C, D, and E and hydrangenol (Fig. **1.2**).[21a–c] Pharmacological activities of these natural products include promotion of the adipogenesis of murine 3T3-L1 cells,[21a] and show antiproliferative activity against mouse splenocytes[21b] and cytotoxic activity against human gastric cancer cell lines and human nasopharyngeal carcinoma cell lines.[21c]



5: Hydrangenol (R^1 = H, R^2 = H)
6: Thunberginol C (R^1 = OH, R^2 = H)
7: Thunberginol D (R^1 = OH, R^2 = OH)

Figure: 1.2

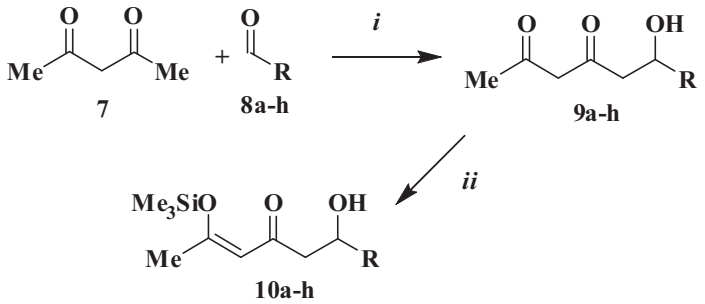
Related 3-aryl-3,4-dihydroisocoumarins[21d] show antifungal activity,[21e] inhibition of rat basophilic leukaemia RBL-2H3 cells,[21f] antiproliferative activity against C57/BL6 mouse splenocytes,[21b] antimalarial activity,[23a] antileukemic activity,[23b] differentiation-inducing activity,[21m] antiallergic activity,[21g,21i] induction of steroidogenesis,[21h] phagocytic activity,[21i] immunomodulatory activity on spleen lymphocyte proliferation (activated by lipopolysaccharide, concanavalin A and phytohaemagglutinin in mice)[21j] antimicrobial activity[21k–m,22] anti-inflammtory and enzyme inhibitory activity.[21n] In a number of natural products, one of the hydroxyl groups of the 3-aryl-3,4-dihydroisocoumarin core structure is glycosylated; this includes, for example, (-)-hydrangenol 40-Oglucoside[21i] and phyllodulcin 8-O-glucoside.[21a,21l]

Chan and co-workers were the first to report[13a,d] the $TiCl_4$-mediated [3+3] cyclization[12c] of 1,3-bis(trimethylsilyloxy)-1,3-butadienes[12a] with 3-silyloxy-2-en-1-ones which provides a versatile method for the synthesis of various functionalized arenes and hetarenes. In recent years, Langer *et al*. studied the application of this reaction to the synthesis of various functionalized arenes.

Recently, Langer *et al*. reported the synthesis of dibenzo[b,d]pyran-6-ones based on a [3+3] cyclization/lactonization strategy.[24] Herein, I report what are, to the best of my knowledge, the first domino[10a,b] ′[3+3] cyclization/lactonization′ reactions of 1,3-bis(silyloxy)-1,3-butadienes with 1-hydroxy-5-silyloxy-4-en-3-ones. These reactions proceed with very good regioselectivity and provide a convenient approach to 3-aryl-3,4-dihydroisocoumarins which are not readily available by other methods.

1.2.2 Results and Discussion

The reaction of the dianion of acetylacetone (**7**) with aldehydes **8a-h** afforded condensation products **9a-h** (Scheme **1.4**, Table **1.2**) by following a known procedure.[11a] These condensation products **9a-h** resulted in chemoselective formation of 1-aryl-1-hydroxy-5-silyloxy-4-en-3-ones **10a-h** when reacted with Me_3SiCl in presence of NEt_3 as a base. Notably A silylation of the hydroxy group was not observed.



Scheme 1.4: Synthesis of 1-aryl-1-hydroxy-5-silyloxy-4-en-3-ones **10a-h**: *i*: 1) **7**, 2.5 LDA, THF, 1 h, 0 °C; 2) **8a-h**, -78 → 20 °C, 14 h; 3) $NaHCO_3$, H_2O; *ii*: NEt_3, Me_3SiCl, CH_2Cl_2, 20 °C, 14 h.

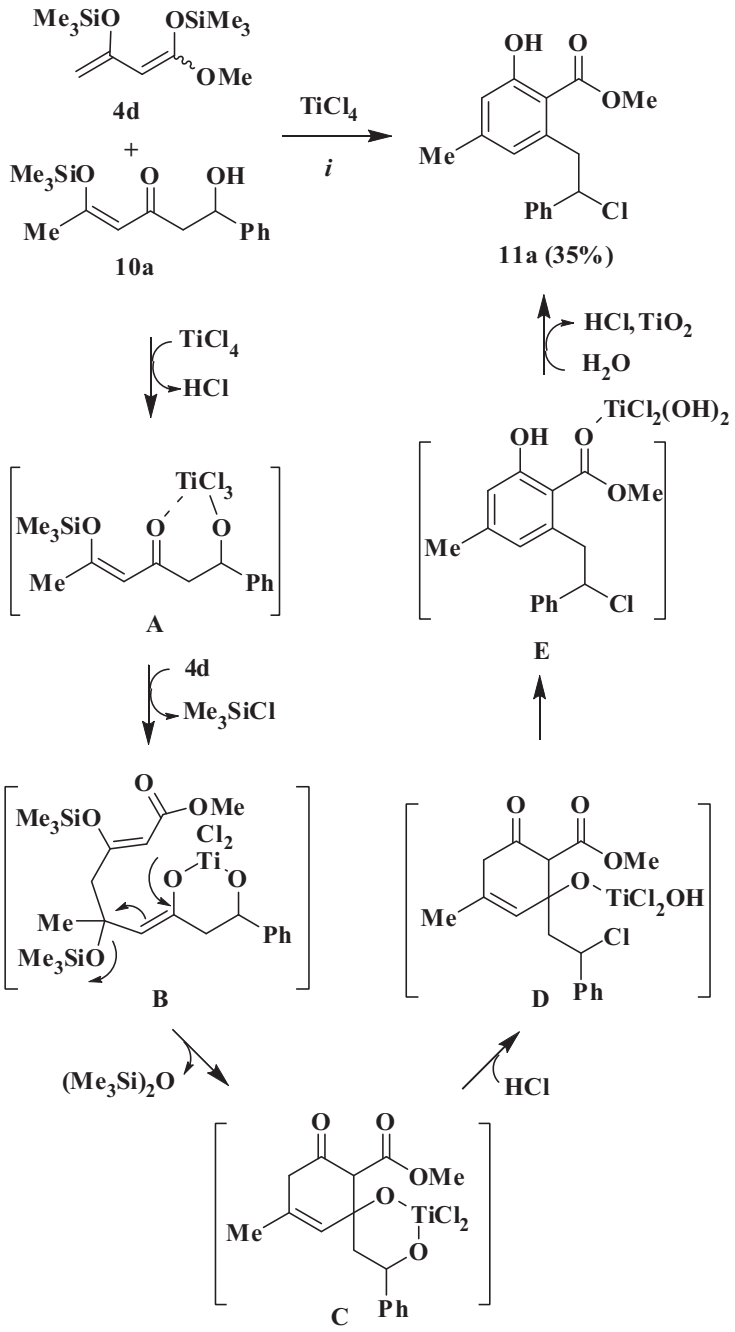
Table 1.2: Synthesis of 1-hydroxy-5-silyloxy-4-en-3-ones **10a-h.**

9,10	*R*	*% (9)*[a]	*% (10)*[a]
a	Ph	70	86
b	2-FC_6H_4	56	83
c	2,3-$(MeO)_2C_6H_3$	65	80
d	3-MeC_6H_4	63	90
e	4-MeC_6H_4	66	92
f	4-EtC_6H_4	74	95
g	4-ClC_6H_4	60	88
h	3-Pyridyl	45	78

[a] Yields of isolated products

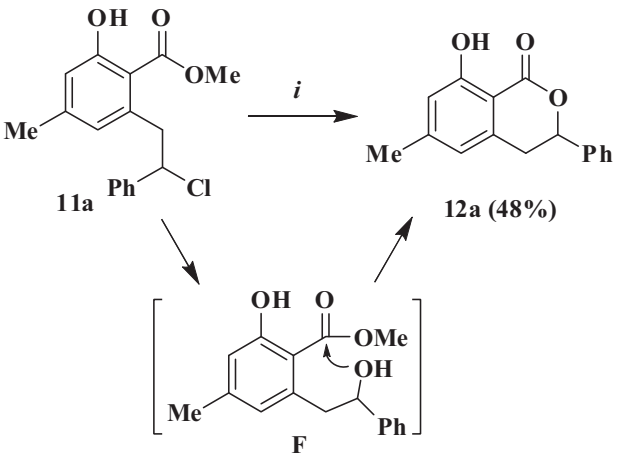
The $TiCl_4$-mediated [3+3] cyclization of 1-phenyl-1-hydroxy-5-silyloxy-4-en-3-ones **10a** with 1,3-bis(silyloxy)-1,3-butadiene **4d**, readily available from methyl acetoacetate,[13a,d] afforded the novel 6-(2-phenyl-2-chloroethyl)salicylate **11a** (Scheme **1.5**). The cyclization proceeded with excellent regioselectivity and best yield was obtained when reaction was carried out in concentrated solution. Moreover, the reaction conditions were also optimized and poor yield was obtained when reaction time was kept small (5-6 hrs). In fact, the formation of the other regioisomer, 4-(2-phenyl-2-chloroethyl)salicylate, was not observed. The moderate yield of **11a** (35%) can be explained by practical problems during the chromatographic purification due to its sticky nature with the glass.

The regioselective formation of product **11a** might be explained by chelation control. The reaction of $TiCl_4$ with **10a** gave intermediate **A** and hydrogen chloride. The chelation of Ti(IV) by the hydroxyl and the carbonyl group facilitates the conjugate addition of the (most reactive) terminal carbon atom of **4d** to **A** to give intermediate **B** which underwent a cyclization to give intermediate **C**. The reaction of HCl with the carbon atom attached to the phenyl group resulted in nucleophilic substitution and formation of intermediate **D** which underwent aromatization to give intermediate **E**. Product **11a** was formed upon aqueous work-up. Interestingly, the presence of the *free* hydroxy group of **10a** was important to achieve a high degree of regioselectivity. The presence of a methoxy rather than a hydroxyl group resulted in the formation of a mixture of regioisomers.



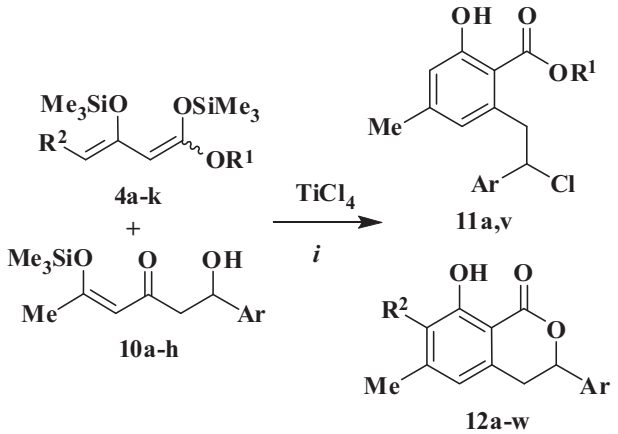
Scheme 1.5: Possible mechanism of the formation of **11a**: *i*: 1) $TiCl_4$, CH_2Cl_2, –78 → 20 °C, 14 h; 2) $NaHCO_3$, H_2O.

Stirring the solution of **11a** in wet THF in the presence of silica gel afforded the 3-phenyl-3,4-dihydroisocoumarin **12a** in 48% yield (Scheme **1.6**). The formation of **12a** can be explained by acid-mediated hydrolysis of the chloride to give intermediate **F** and subsequent lactonization.



Scheme 1.6: Synthesis of **12a**: *i*: SiO_2, wet THF, 14 h

The [3+3] cyclization of **10a** with 1,3-bis(silyloxy)-1,3-butadiene **4d** afforded **11a** which was transformed into lactone **12a** by stirring in the presence of wet silica gel for 14 h. The [3+3] cyclization of **10a** with 1,3-bis(silyloxy)-1,3-butadienes **4f-i**, containing a longer alkyl group attached to carbon atom C4, directly afforded the 3-phenyl-3,4-dihydroisocoumarins **12b-e**. The formation of **12b-e** can be explained by [3+3] cyclization and subsequent hydrolysis and lactonization during the aqueous work-up and/or silica gel chromatography. The cyclization of **10a** with 1,3-bis(silyloxy)-1,3-butadienes **4d,k** resulted in the formation of 6-(2-phenyl-2-chloroethyl)salicylates **11a,k**. The cyclization of various 1,3-bis(silyloxy)-1,3-butadienes with **10b-h**, containing phenyl groups with electron-withdrawing or –donating substituents, directly afforded the 3-aryl-3,4-dihydroisocoumarines **12f-w** (except for the reaction of **10g** with **4k** which gave **11v**).



Scheme 1.7: Synthesis of **11a,v** and **12a-w**: *i*: 1) $TiCl_4$, CH_2Cl_2, −78 → 20 °C, 14 h; 2) $NaHCO_3$, H_2O; 3) silica gel chromatography (EtOAc / heptanes).

The silica gel chromatography generally proved to be important for the hydrolysis and lactonization to occur. In most reactions the direct formation of 2,3-dihydroisocoumarines was observed. The formation of products **11** mainly occurred when the phenyl-substituted silyl enol ether **10a** was employed. In this series, the choice of the 1,3-bis(silyloxy)-1,3-butadiene seems to have a significant influence on the product distribution. On the other hand, different products were obtained for reactions of one and the same 1,3-bis(silyloxy)-1,3-butadiene with different silyl enol ethers **10**. It was mentioned above that products **11** can be transformed into lactones **12** by stirring in the presence of wet silica gel. This result suggests that the quality and nature of the silica gel and of the solvent employed for the chromatographic purification also have an influence on the product distribution. In addition, the individual handling of each reaction may play a role. This includes, for example, the time required for the aqueous work-up or the preparation of the crude material for chromatography (concentration of a solution of the crude crude product in the presence of silica gel and addition of the solid residue on the top of the column or, alternatively, direct addition of the oily crude product by syringe without silica gel). In addition, the quality of the Lewis acid should have some influence (an older charge of $TiCl_4$ may be partly hydrolyzed and contains HCl).

Table 1.3: Synthesis of salicylates **11a,v** and 3-aryl-3,4-dihydroisocoumarins **12a-w**

10	*4*	*11,12*	R^1	R^2	*Ar*	*% (11)*[a]	*% (12)*[a]
a	**d**	**a**	Me	Me	Ph	35	48 [c]
a	**f**	**b**	Me	Et	Ph	0	33
a	**g**	**c**	Me	*n*Hex	Ph	0	57
a	**h**	**d**	Me	*n*Non	Ph	0	53
a	**i**	**e**	Me	$(CH_2)_2CH=CH_2$	Ph	0	42
b	**c**	**f**	Bn	H	$2\text{-}FC_6H_4$	0	50
b	**e**	**g**	Et	Me	$2\text{-}FC_6H_4$	0	46
c	**c**	**h**	Bn	H	$2,3\text{-}(MeO)_2C_6H_3$	0	38
c	**e**	**i**	Et	Me	$2,3\text{-}(MeO)_2C_6H_3$	0	35
d	**a**	**j**	Me	H	$3\text{-}MeC_6H_4$	0	42
d	**e**	**k**	Et	Me	$3\text{-}MeC_6H_4$	0	45
d	**f**	**l**	Me	Et	$3\text{-}MeC_6H_4$	0	54
d	**g**	**m**	Me	*n*Hex	$3\text{-}MeC_6H_4$	0	58
e	**d**	**n**	Me	Me	$4\text{-}MeC_6H_4$	0	43
e	**i**	**o**	Me	$(CH_2)_2CH=CH_2$	$4\text{-}MeC_6H_4$	0	38
e	**j**	**p**	Me	$(CH_2)_2$ Ph	$4\text{-}MeC_6H_4$	0	40
f	**b**	**q**	Et	H	$4\text{-}EtC_6H_4$	0	48
g	**a**	**r**	Me	H	$4\text{-}ClC_6H_4$	0	55
g	**d**	**s**	Me	Me	$4\text{-}ClC_6H_4$	0	50
g	**f**	**t**	Me	Et	$4\text{-}ClC_6H_4$	0	53
g	**g**	**u**	Me	*n*Hex	$4\text{-}ClC_6H_4$	0	55
g	**k**	**v**	Me	Cl	$4\text{-}ClC_6H_4$	28	0
h	**a**	**w**	Me	H	3-Pyridyl	0	37

[a] Yields of isolated products; [b] prepared from **11a**; [c] prepared from **11b**

All the products were characterized by spectroscopic methods. The structures of **12f**, **12i**, **12l** and **12w** were independently confirmed by X-ray crystal structure analyses (Figures **1.3-1.6**). Inspection of the x-ray crystal structures shows the aryl group attached at C-3 is twisted out of plane in all cases. An intramolecular Hydrogen bonding O–H···O was observed, after calculating the position of OH from difference map and refinement, between hydrogen of OH at C-8 and oxygen at C-1. Moreover, CH (C-3), in all cases was twisted out of the plane from rest of the atoms of isocoumarin core.

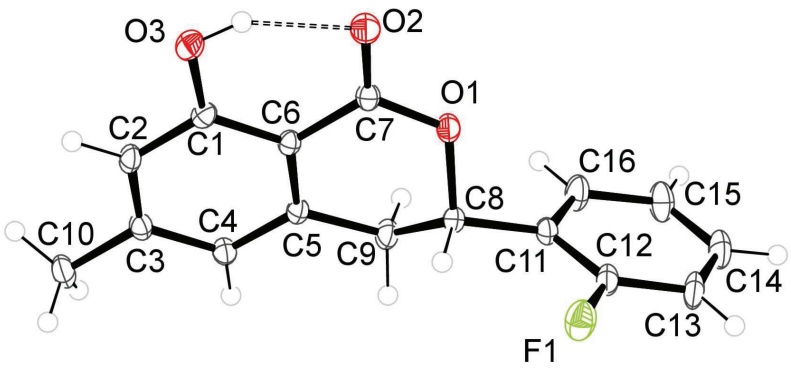


Figure 1.3: Crystal structure of **12f**, the position of the OH-proton was calculated from the difference map and refined freely.

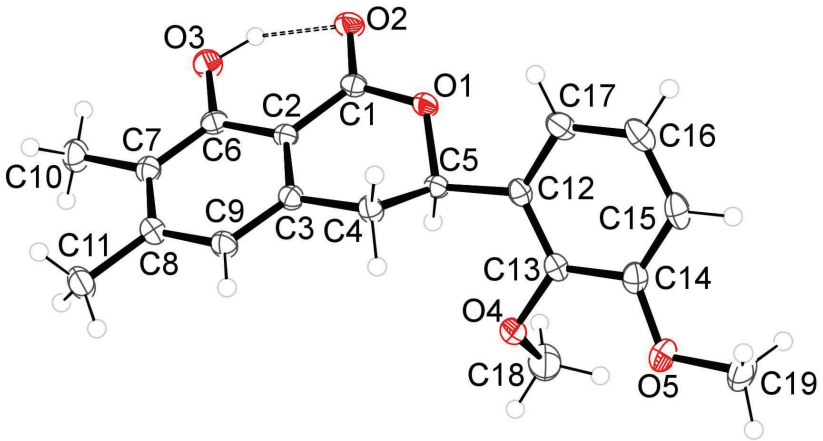


Figure 1.4: Crystal structure of **12i**, the position of the OH-proton was calculated from the difference map and refined freely.

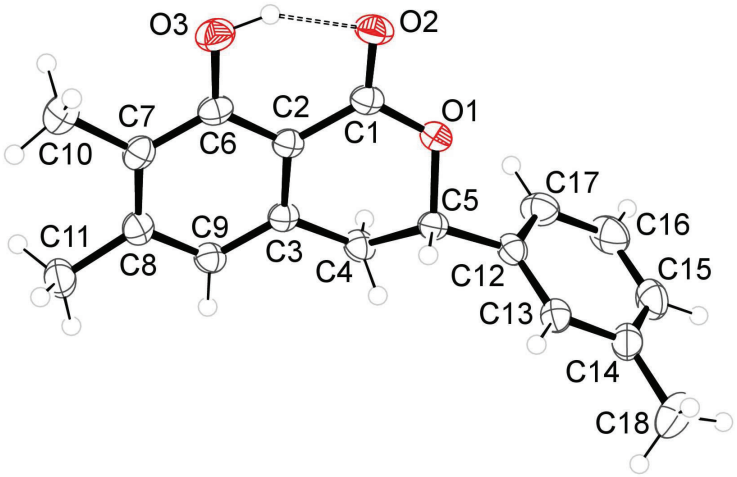


Figure 1.5: Crystal structure of **12l**, the position of the OH-proton was calculated from the difference map and refined freely.

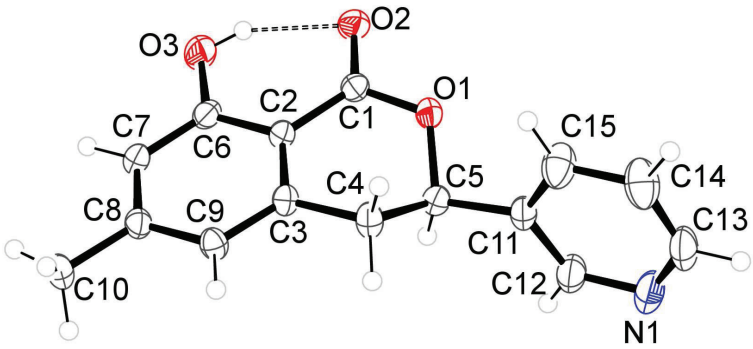


Figure 1.6: Crystal structure of **12w**, the position of the OH-proton was calculated from the difference map and refined freely.

1.2.3 Conclusion

In conclusion, I reported a convenient synthesis of 3-aryl-3,4-dihydroisocoumarins by domino′ [3+3] cyclization / lactonization′ reactions of 1,3-bis(silyloxy)-1,3-butadienes with 1-hydroxy-5-silyloxy-4-en-3-ones. These reactions proceed by regioselective [3+3] cyclization to give 6-(2-aryl-2-chloroethyl)salicylates and subsequent silica gel-mediated lactonization. A smooth lactonization is observed for methyl, but not for ethyl, *iso*propyl and benzyl salicylates.

Synthesis of Sterically Encumbered Biaryls based on a Copper(I)-Catalyzed Arylation / [3+3] Cyclocondensation′ Strategy

2.1 Introduction

The biaryl sub-unit is found in a wide variety of natural products, including alkaloids, coumarins, flavonoids, lignans, polyketides, tannins, terpenes and peptides.[25a,b] Compounds bearing biaryl moiety also find application as chiral scaffolds in many chiral ligands (phosphanes, pyridines, etc.), chiral phases for chromatography and chiral liquids crystals to name the most important.[25a,b] These sterically hindered biaryls are of considerable pharmacological importance. Simple biaryl derivative aucuparin (Fig. **2.1**),[25c] have shown antifungal activities and have been isolated from *Sorbus aucuparia.* Other simple biaryl cynandione A (Fig. **2.2**) have been isolated from *Cynachum wilfordii*. Cynandione A and have shown the property to protect cultured cortical neurons from toxicity of H_2O_2, L-glutamate and kainate.[25d]

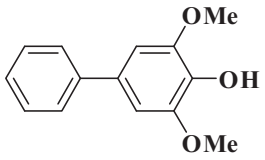
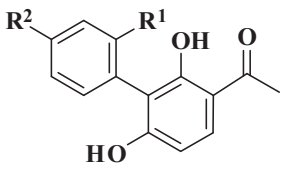
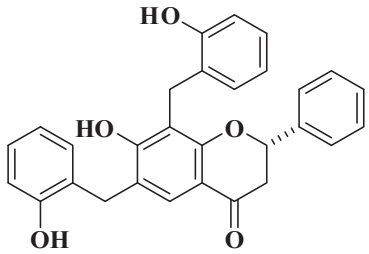


Figure 2.1: aucuparin isolated from natural sources [25c]

The simple biaryls Cynandione A-C are effective against hepatocytes, human bladder carcinoma T-24 cells, epidermoid carcinoma KB cells, and human hepatoma PLC/PRF/5 cells.[26] 3-Arylsalicylates are also present in many flavones (e.g. 2,3-dihydroamentoflavone, obtained from *selagenella tamariscina*, which is active against type-2 diabetes and obesity.[27a] Bartramiaflavone,[27b] robustaflavone, obtained from *selagenella dicatula*, is effective against hepatitis B.[27c] Dichamanetin, obtained from *U. chamae*, is effective against gram positive bacteria.[27d,e] For some derivatives, inhibition of the human liver cathepsin B and K has been reported.[27f,g] Anastatin A, which was isolated from *anastatica heirochuntica*,[28] possesses a benzofuran moiety and shows hepativeprotective activity.[29]



Cynandione A



Dichamanetin

Fig. 2.2: Pharmacologically important biaryls isolated from natural sources

Many pharmacologically active biaryl natural products, such as picropodophyllone, can be formally regarded as sterically encumbered 4-arylphenols.[30] Others, such as dioncophylleine A, contain a naphthalene and an isoquinoline moiety.[31] Flavidine may be regarded as a complex bridged biaryl derivative.[32] A number of natural products, such as knipholone, 6'-*O*-methylknipholone or (+)-asphodelin, contain an anthraquinone moiety.[33] Other compounds, e. g. secalonic acid A or globulixanthone E, contain a bixanthenyl substructure.[34]

A classic approach to sterically encumbered biaryls is based on reactions of diazonium salts. However, this method is not generally applicable.[35] The most important synthetic approach to biaryls relies on Pd(0)-catalyzed cross-coupling reactions (e.g., Suzuki reactions).[7b] Although this approach is broadly applicable, the synthesis of sterically encumbered and functionalized products can be sometimes difficult or not possible at all. Although, recently, a number of new ligands have been developed which allow to tackle these problems.[36] But the regioselective preparation of the corresponding aryl halides, triflates stannanes and boronic acids, which have to be used as adducts, is still a difficult and time consumig task in many cases. Arenes are alternatively available by using dienes in cyclization reactions. Some years ago, Chan *et al.* developed[13] a convenient approach to salicylates by [3+3] cyclizations[12c] of with 3-trimethylsilyloxy-2-en-1-ones with 1,3-bis (trimethylsilyloxy)-1,3-dienes.[12a]

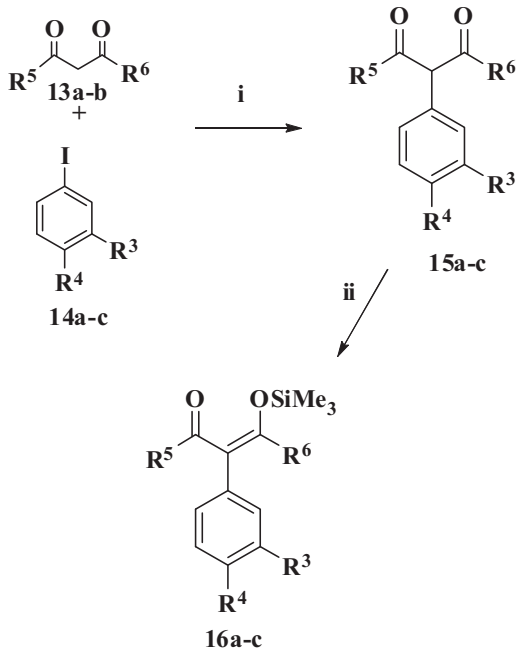
Recently, Langer *et al*. reported the synthesis of 3-arylsalicylates based on cyclization reactions of 4-aryl-1,3-bis(silyloxy)-1,3-butadienes with various 1,3-dielectrophiles.[37] Herein, I report what are, to the best of my knowledge, the first synthesis of sterically encumbered 5-arylsalicylates by combination of a CuI–proline-catalyzed arylation with [3+3] cyclizations. These

reactions proceed with very good regioselectivity and provide a convenient approach to 5-arylsalicylates which are not readily available by other methods. Their synthesis by direct palladium-catalyzed coupling reactions would be extremely difficult, because the required salicylate-derived aryl halides or triflates are not readily available.

2.2 Results and discussion

The CuI-proline-catalyzed arylation[38] of 1,3-diketone **13a** with aryl iodides **14a-c** afforded the 2-aryl-1,3-diketones **15a-c** in 85-90% yield (Scheme **2.1**, Table **2.1**). Aryl iodides **14a-c** were prepared by a method reported by He *et al.*[39] The silylation of **15a-c** gave the 3-silyloxy-2-en-1-ones **16a-c**. The known 1,3-bis(silyloxy)-1,3-dienes **4a-k** were prepared in two steps from the corresponding β-ketoesters.[28] The $TiCl_4$-mediated [3+3] cyclocondensation of 2-aryl-3-silyloxy-2-en-1-ones **16a-c** with **4a-k** afforded the biaryls **17a-n** (Scheme **2.2**, Table **2.2**). During the optimization, it turned out that the reactions proceed very well in a highly concentrated solution. The reaction of **16a** with 1,3-bis(silyloxy)-1,3-butadienes derived from acetylacetone and benzoylacetone proved to be unsuccessful. This can be explained by their lower reactivity compared to dienes derived from β-ketoesters. The nature of the aryl group of enones has a small influence on the yield of the cyclization reactions. CF_3 substituted enones gave comparatively lower yield because of the electron withdrawing nature of CF_3 group thereby reducing the reactivity of dienophile and reducing the overall yield of reaction.

The substitution pattern of dienes has a strong influence on the yields. The best yields were obtained for products derived from non-substituted diene **4a** which is derived from methyl acetoacetate. This might be explained by cleavage of the benzyl ester moiety by $TiCl_4$. Since both dienes are closely related with respect to their structure, this result indicates that the individual quality of the diene and reagents employed also have a strong influence. Therefore, the diene electrophiles used were entirely pure and distilled, the dienes used were freshly synthesized in order to avoid polymeric impurities and the $TiCl_4$ employed was new and was added to the reaction mixture dropwise. Chromatographic purification also plays an important role. The yields of the products derived from 4-substituted dienes are often slightly lower than the yields of the products derived from **4a**.

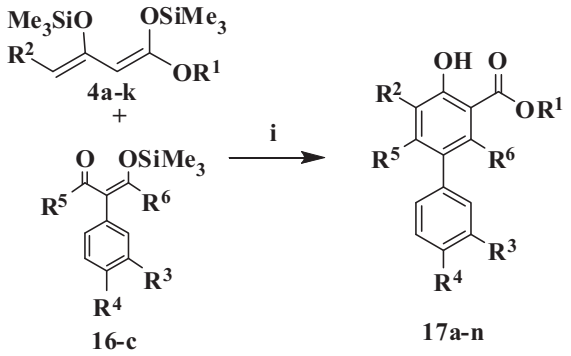


Scheme 2.1: Synthesis of **16a-c**, *i*: K_2CO_3, CuI 10 mol %, L-proline 20 mol%, DMSO, 90 °C, 6-12 h; *ii*: Me_3SiCl, NEt_3, C_6H_6, 20 °C, 72 h.

Table 2.1: Synthesis of 3-aryl-1,3-diketones **15a-c** and 3-silyloxy-2-en-1-ones **16a-c**

13	*14*	*15,16*	R^5=R^6	R^3	R^4	*% (15)* [a]	*% (16)* [a]
a	**a**	**a**	Et	H	H	74	90
b	**b**	**b**	Me	H	CO_2Et	72	80
b	**c**	**c**	Me	CF_3	H	65	86

[a] Yields of isolated products



Scheme 2.2: Synthesis of **17a-n**; *i*: $TiCl_4$, CH_2Cl_2, –78 → 20 °C, 20 h

Table 2.2: Synthesis of 4-hydroxybiphenyl-3-carboxylate (17a-n)

16	*4*	*17*	R^5=R^6	R^3	R^4	R^1	R^2	%(17)[a]
a	**a**	**a**	Et	H	H	OMe	H	55
a	**b**	**b**	Et	H	H	OEt	H	43
a	**c**	**c**	Et	H	H	OCH_2Ph	H	36
b	**a**	**d**	Me	H	CO_2Et	OMe	H	60
b	**b**	**e**	Me	H	CO_2Et	OEt	H	45
b	**d**	**f**	Me	H	CO_2Et	OMe	Me	43
b	**j**	**g**	Me	H	CO_2Et	OMe	$(CH_2)_2Ph$	35
c	**a**	**h**	Me	CF_3	H	OMe	H	43
c	**b**	**i**	Me	CF_3	H	OEt	H	35
c	**e**	**j**	Me	CF_3	H	OEt	Me	37
c	**f**	**k**	Me	CF_3	H	OMe	Et	47
c	**g**	**l**	Me	CF_3	H	OMe	n-hex	43
c	**i**	**m**	Me	CF_3	H	OMe	$(CH_2)_2CH=CH_2$	44
c	**k**	**n**	Me	CF_3	H	OMe	Cl	32

[a] Yields of isolated products

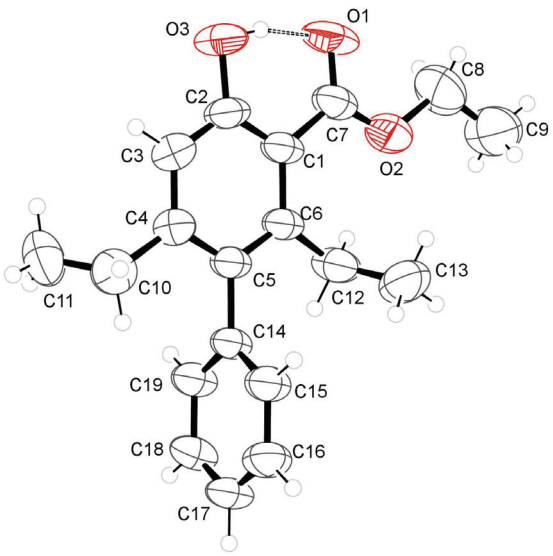


Figure 2.3: Crystal structure of **17b**

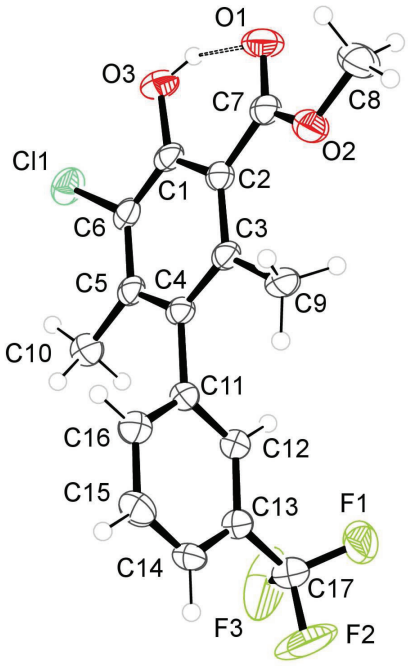
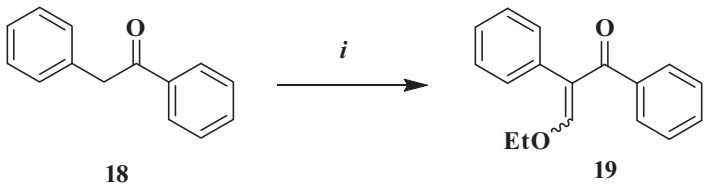


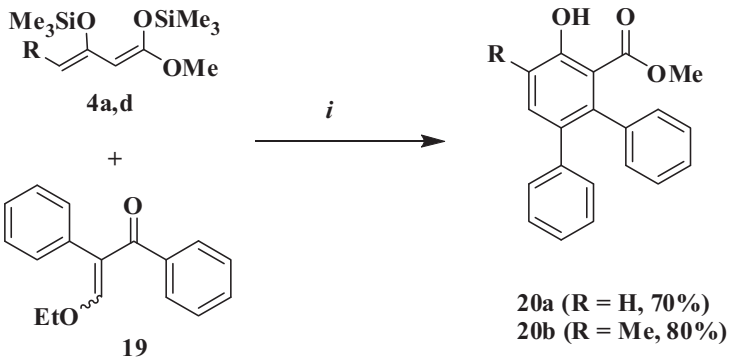
Figure 2.4: Crystal structure of **17n**

In addition, Sterically more hindered and functionalized biaryls **20**, were prepared from different enone **19**, which was prepared quite in a different manner, treating 1,2-diphenylethanone with ethyl chloroformate in presence of acetic anhydride (Scheme **2.3** and Scheme **2.4**). Enone **19** when treated with 1,3-bis(silyloxy)-1,3-butadienes **4a,d** resulted in the formation of **20a,b** in 70% and 80% yields.



18 **19**

Scheme 2.3: Synthesis of **19**; *i*: **18**, Ac_2O, $HC(OEt)_3$, reflux, 8 hr.



Scheme 2.4: Synthesis of **20a,b**; *i*: $TiCl_4$, CH_2Cl_2, –78 → 20 °C, 20 h.

All products were characterized by spectroscopic methods. The structures of **17b**, **17n** and **20b** were independently confirmed by X-ray crystal structure analyses (Figures **2.3**, **2.4** and **2.5** respectively). The two aryl moieties are twisted out of plane in case of **17b** and **17n**, while in case of **20b** all the three aryl groups are twisted out of plane. An intramolecular hydrogen bonding O–H···O is present in all structures after calculating the position of OH from difference map and refinement.

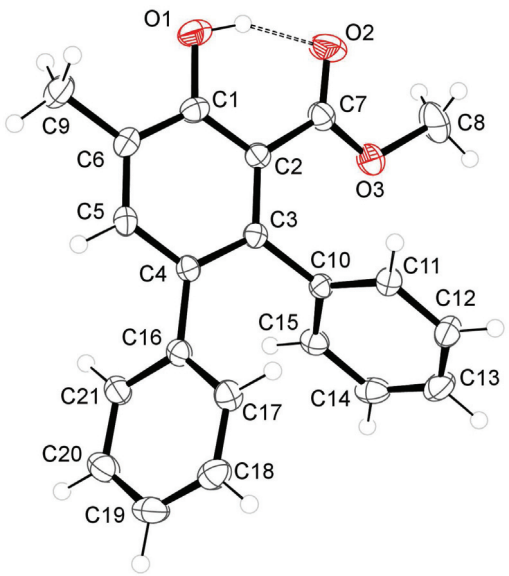


Figure 2.5: Crystal strucure of **20b**

2.3 Conclusion

In short, I prepared various sterically encumbered biaryls by CuI-proline catalysed reactions followed by [3+3] cyclocondensation reactions. Their synthesis by direct palladium-catalyzed coupling reactions would be extremely difficult, because the required salicylate-derived aryl halides or triflates are not readily available. So this method provides a good strategy for the synthesis of 5-arylsalicylates or sterically hindered and unsymmetrical functionalized biaryls**.**

Synthesis of 8,9-Disubstituted Fluoranthenes by Domino Twofold Heck / Electrocyclization / Dehydrogenation of 1,2-Dibromoacenaphthylene

3.1 General Introduction to Heck Reaction

The Heck reaction was discovered by Heck in 1968[40] and then developed by Mizoroki and Heck in the 1970's. It is the palladium catalyzed C-C coupling between aryl halides or vinyl halides with activated alkenes in the presence of palladium(0) catalyst and a base.[41] Palladium(II) acetate or Palladium(II) chloride in combination with different ligands, such as triphenyl phosphine (PPh_3), S-Phos, X-Phos, tricyclohexylphosphine (PCy_3), 2,2'-bis(diphenylphosphino)-1,1'-binaphthyl (BINAP), were used in this reaction. Phosphine ligands stabilize palladium in its oxidation state zero in the form of stable PdL_4 or PdL_3 species. There are many choices of the base used in this reaction, such as triethylamine, diisoproylamine, potassium carbonate, sodium acetate.[42] The reactivity depends on the substituted olefins, more substituted olefins results in lower reaction. However, electron poor olefins provided higher yields (electron withdrawing groups such as ester, ether, carboxylic acid, nitriles, located at the olefin). The type of leaving group also plays an important role. The reactivity order is I > Br > Cl.[43] The mechanism of the Heck reaction involves the oxidative addition, migratory insertion of the olefins and then β- hydride elimination.[44] The combination of the Heck cross-coupling reaction with electrocyclization reactions provide a convenient access to a variety of carbacyclic frameworks. The Heck reaction has been widely used as a key step in the total synthesis of natural products, for the preparation of polymers, pharmaceuticals, and hydrocarbons.[45]

Since last couple of years, Prof Langer's research group has extensively studied twofold Heck cross coupling reactions of 2,3-dibromobenzofuran (**a**),[46a] 2,3-dibromothiophene (**b**),[46b] 2,3-dibromo-N-methylindole (**c**),[46c] 2,3-dibromofuran (**d**), 2,3-dibromoindenone (**e**),[46d] 2,3-dibromo naphthaquinone (**f**).[46e] (Figure **3.1**). The electrocyclization and dehydrogenation of Heck products provided upon heating in the presence of Pd/C a variety of aromatized products.

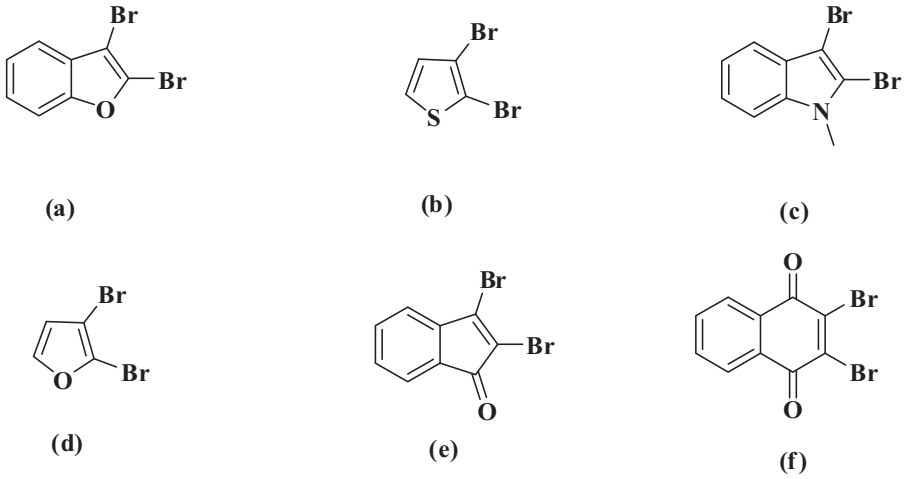


Figure 3.1: Heck Reaction Studies on halogenated substrates in Prof Langer's Group

3.2 Introduction to Functionalized Fluoranthenes

Polycyclic aromatic hydrocarbons (PAHs) are formed by the incomplete combustion of organic materials.[48] They possess useful applications in the field of material sciences, due to their optical properties, thermo- and light-sensitivity, conductivity, liquid crystal properties, and their heat and corrosion resistance.[49] Polycyclic aromatic hydrocarbons containing a five-membered ring constitute an important subclass of PAHs.[50] Fluoranthene, the parent core structure of such molecules,[51] is the third most abundant constituent of coal tar (after naphthalene and phenanthrene).[52] Fluoranthene derivatives are also found in oil, cigarette smoke and smoke derived from open fires, smoked and grilled foods, and in waste water.[53]

These bowl-shaped PAH, Fluoranthenes, have been used as a ligand in chromium(0)-π-complexes.[54] Fluoranthene derivatives possess characteristic luminescence properties such as anomalous fluorescence quenching,[52] and have been used as molecular sensors[52e] and organic semiconductors,[52f] (Figure **3.2**). Some fluoranthene derivatives have been employed as organic light emitting devices,[52g] as a dopant of molecular crystals for laser spectroscopy,[52h] as efficient blue-light-emitting electroluminescent devices,[52i] and as dyes.[52j] Parent fluoranthenes serve as a synthetic building blocks.[55] Some fluoranthene derivatives have been reported to possess antiviral activities.[56] Moreover, fluoranthene also constitutes a partial structure of corannulene and thus of C_{60} fullerene and its higher homologues.[57]

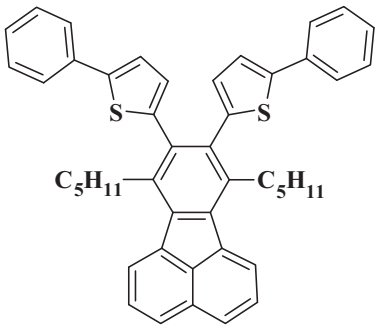


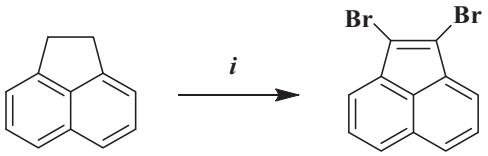
Figure 3.2: Fluoranthene derivative used as organic semi-conductor.[52f]

3.3 Results and discussion

A number of methods for the synthesis of fluoranthenes have been reported.[58] For example, they have been prepared by [4+2] cycloadditions of acenaphthene with thiophenes or 2,3,4,5-tetraphenylcyclopentadienone (tetracyclone). Despite their great utility, some syntheses lack general applicability (with regard to the substitution pattern) or suffer from harsh conditions and/or low yields. Therefore, the development of alternative synthetic strategies to substituted fluoranthenes is an important task.

Benzene derivatives have been prepared by double Heck reactions of aliphatic 1,2-dibromoalkenes to give hexatrienes and subsequent thermal 6π-electrocyclization of the latter.[59] In recent years, we have studied the synthesis of various heterocycles, such as carbazoles, benzothiophenes, dibenzofurans, and benzimidazoles, by application of this approach.[46a-c,60] The electrocyclization can proceed smoothly, if the central double bond of the triene system is not involved in a stable aromatic 6π system. It occurred to us that 1,2-dibromoacenaphthene might be an interesting substrate for domino Heck / electrocyclization reactions and could allow a convenient synthesis of fluoranthene derivatives. While Suzuki-Miyaura reactions of 1,2-dibromoacenaphthene are known,[61] Heck reactions have, to the best of our knowledge, not been reported so far.[62] Herein, I report that domino twofold Heck / electrocyclization / dehydrogenation reactions of 1,2-dibromoacenaphthene provide a convenient access to 8,9-disubstituted fluoranthenes which are not readily available by other methods.

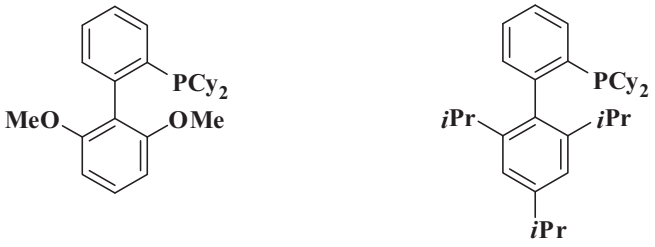
1,2-Dibromoacenapthylene (**22**) was prepared, following a known procedure,[63] by reaction of 1,2-dihydroacenaphthylene (**21**) with NBS and dibenzoyl peroxide (Scheme **3.1**).



21 **22**

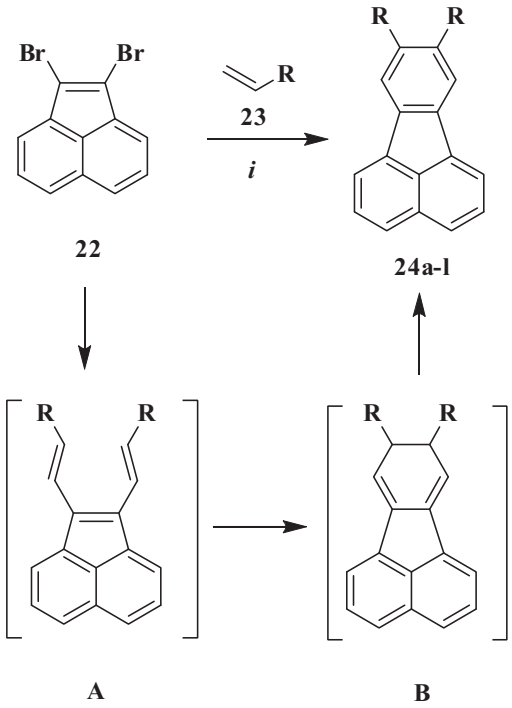
Scheme 3.1: *i*, NBS, CCl_4, dibenzoyl peroxide, reflux, 2 h.

The Heck reaction of **22** with acrylates and styrenes (**23a-l**), afforded the fluoranthenes **24a-l** in 56-82% yields (Scheme **3.2**, Table **3.1**). The formation of the products can be explained by twofold Heck reaction to give intermediate **A**, electrocyclization (**B**), and subsequent dehydrogenation. The reactions failed when $Pd(PPh_3)_4$ was used as the catalyst. However, when Buchwald ligands, $\mathbf{L_1}$ and $\mathbf{L_2}$ (Figure **3.3**)[47] with palladium(II) acetate were used the reaction was successful and best results were obtained for biaryl monophosphine ligand $\mathbf{L_2}$.



L1 = S-Phos **Cy = Cyclohexyl** **L2 = X-Phos**

Figure 3.3: Biaryl monophosphine ligands developed by Buchwald and coworkers.[47]



Scheme 3.2: Synthesis of **24a-l**. *Conditions*: Method 1, (*ii*) ***23***, $Pd(OAc)_2$ (5 mol%), X-Phos (10 mol%), NEt_3, DMF, 90 °C, 12 h. Method 2, (*iii*) ***23***, $Pd(OAc)_2$ (5 mol%), X-Phos (10 mol%), NEt_3, DMF, 110 °C, 12 h

Table 3.1. Synthesis of Functionalized Fluoranthenes **24a-l**

23,24	*R*	*% (24)[a] Method 1*	*% (24)[a] Method 2*
a	CO_2Me	68	Traces [c]
b	CO_2Et	73	- [b]
c	CO_2nBu	77	- [b]
d	CO_2iBu	81	Traces [c]
e	CO_2tBu	82	Traces [c]
f	CO_2nHex	69	- [b]
g	CO_2(2-Ethylhexyl)	71	- [b]
h	CO_2iOct	65	- [b]
i	4-MeC_6H_4	Traces	66
j	4-(MeO)C_6H_4	Traces	74
k	4-FC_6H_4	- [b]	59
l	2-Pyr	Traces	56

[a] Yields of isolated products; [b] experiment not carried out; [c] Formation of complex mixture.

The reaction conditions were optimized for the synthesis of **24e** (derived from an acrylate) and **24i** (derived from a styrene) (Table **3.2**). The best yields of **24e** and **24i** were obtained when $Pd(OAc)_2$ was used as the catalyst together with the ligand X-Phos, **(L_2)** and when the reaction was carried out at 90 ^oC in DMF. The temperature played an important role. The reactions of acrylates were carried out at 90 ^oC (product **24e**), while reactions of styrenes were performed at 110 ^oC (product **24i**). A slight increase or decrease of the temperature resulted in dramatically lower yields. The choice of the solvent also played an important role. No conversion was observed for nonpolar solvents, such as benzene or toluene. The use of acetonitrile resulted in the formation of the desired products, albeit, in low yields. The successful employment of DMF can be explained by its polarity and high boiling point. As the major side-product the formation of bis(alkenyl)acenaphthenes **A** was observed (5-10% by NMR of the crude product mixture).

Table 3.2: Optimization of the synthesis of **24e** and **24i**

No	*24*	*T [°C]*	*Catalyst*	*Solvent*	*t [h]*	*Yield (%)*[a]
1	**e**	90	$Pd(PPh_3)_4$	DMF	36	-[b]
2	**e**	90	$Pd(PPh_3)_4$	Dioxane	36	-[b]
3	**e**	90	$Pd(PPh_3)_4$	MeCN	36	-[b]
4	**e**	110	$Pd(PPh_3)_4$	DMF	48	-[b]
5	**e**	90	X-Phos/$Pd(OAc)_2$	Dioxane	18	Traces
6	**e**	110	X-Phos/$Pd(OAc)_2$	MeCN	36	-[c]
7	**e**	90	X-Phos/$Pd(OAc)_2$	DMF	12	82
8	**e**	90	S-Phos/$Pd(OAc)_2$	DMF	12	75
9	**e**	110	X-Phos/$Pd(OAc)_2$	DMF	8	-[c]
10	**e**	90	X-Phos/$Pd(OAc)_2$	MeCN	12	35
11	**e**	90	X-Phos/$Pd(OAc)_2$	Benzene	36	-[b]
12	**i**	90	$Pd(PPh_3)_4$	DMF	36	-[b]
13	**i**	110	$Pd(PPh_3)_4$	DMF	36	-[b]
14	**i**	110	$Pd(PPh_3)_4$	Dioxane	36	-[b]
15	**i**	110	X-Phos/$Pd(OAc)_2$	Dioxane	48	Traces
16	**i**	90	X-Phos/$Pd(OAc)_2$	DMF	36	-[b]
17	**i**	110	X-Phos/$Pd(OAc)_2$	DMF	12	66
18	**i**	110	S-Phos/$Pd(OAc)_2$	DMF	12	60
19	**i**	120	X-Phos/$Pd(OAc)_2$	DMF	8	-[c]

[a] Yields of isolated products; [b] no conversion; [c] formation of a complex mixture

Better yields were generally obtained for reactions of acrylates (products **24a-h**, 65-82% entries) than for styrenes (products **24i-l**, 56-74%). This can be explained by the fact that the double bond of acrylates is more electron-deficient and thus more reactive than the double bond of styrenes. Most of the products proved to be fluorescence active.

All the compounds were characterized by spectroscopic methods. The structures of compound **24e** and **24k** were independently confirmed by X-Ray crystal structure analysis (Figures **3.4** & **3.5** respectively). After inspection of X-ray crystal structures it is observed that all four rings of the fluoranthene unit are in plane. In case of **24e**, the *t*butyl moiety and in case of **24k**, the two aryl groups are twisted out of plane from fluoranthene unit, due to steric reasons. An

intramolecular hydrogen bonding O–H···O is also observed in case of **24e** after calculating the position of OH from difference map and refinement. In case of **24e** both of the *t*Bu were placed in different directions due to steric hinderance.

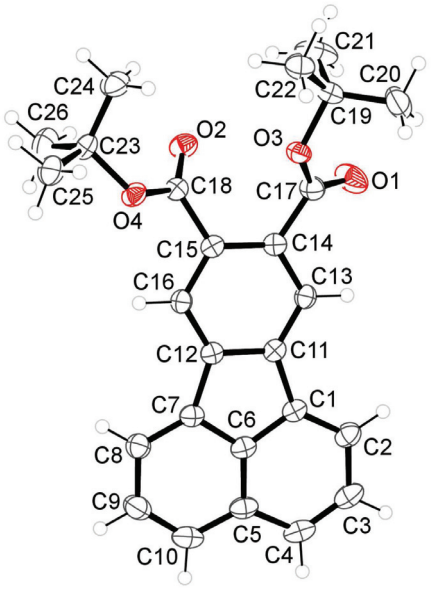


Figure 3.4: Crystal structure of **24e**

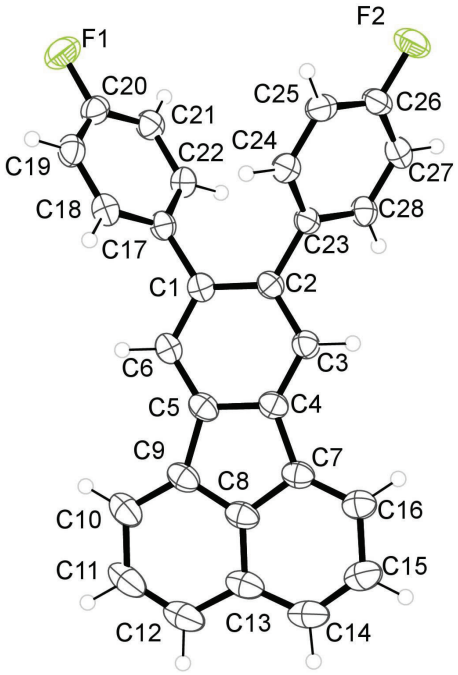


Figure 3.5: Crystal structure of **24k**

The UV/Vis and fluorescence spectra of dimethyl fluoranthene-8,9-dicarboxylate (**24a, table3.1**) is shown in **figure 3.6**. The absorption spectrum for compound **24a** shows four significant transitions at 235 nm (absorption maximum), 295 nm, 356 and 372 nm. The measured emission spectrum (excitation wavelength λ_{ex} = 350 nm) shows two transitions at 450 nm (**5**) and 465 (**6**)**.** Four compounds of this type were measured and all showed similar absorption/emission maxima and transitions **(table 3.3)**. The highest *logε* value was observed for compound (**24a**, **Table 3.1**).

Table 3.3: Assigned transitions of fluoranthene-8,9-dicarboxylate derivates

entry	$\lambda 1_{abs}$ *[nm]*	*logε*	$\lambda 5_{em}$ *[nm]*	$\lambda 6_{em}$ *[nm]*
24 e	235	5.10	450	465
24 a	235	5.39	450	465
24 d	235	5.31	450	465
24 g	235	5.33	450	465

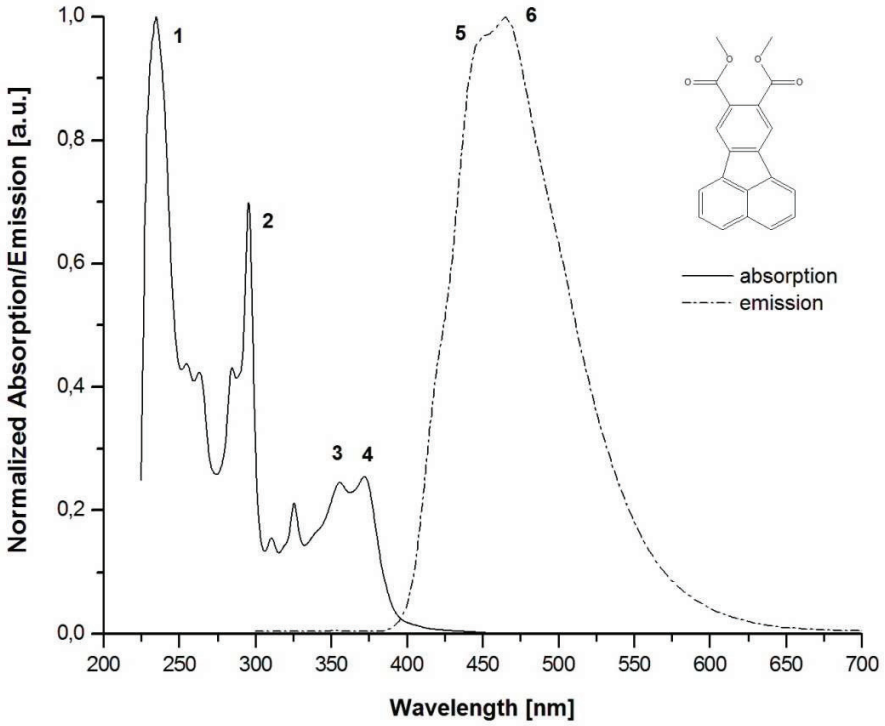


Figure 3.6: Absorption and Emission spectra of compound (**24a**, **Table 3.1**)

3.4 Conclusion

In short, I have reported a new synthesis of fluoranthenes by domino twofold Heck / electrocyclization / dehydrogenation reactions of 1,2-dibromoacenaphthene. Moreover, the reaction conditions were also optimized and best reaction conditions have also been reported. For electrocyclization reactions to occur smoothly, the central double bond of the triene system must not be involved in a stable aromatic 6π system. Because the double bond C1-C2 of acenaphthene possesses the character of an alkene, the electrocyclization proceeds in good yields.

Synthesis of Trifluoromethyl-Substituted Di- and Terphenyls by Site-Selective Suzuki-Miyaura Reactions of 1,4-Dibromo-2-(trifluoromethyl)benzene

4.1 General Introduction to Suzuki-Miyaura reaction

The Suzuki-Miyaura reaction has become a most significant tool for the synthesis of C-C bonds. Among the various cross coupling reactions, the Suzuki-Miyaura reaction is widely used to prepare compounds which are pharmacological active and used in pharmaceutical industries.[64] The reactions involve, for example, the palladium catalyzed cross coupling between organoboron compounds and aryl halides. The scope of the reaction is not restricted to aryl derivatives, but includes also alkyl, alkenyl and alkynyl compounds. The reaction also works well with triflates (the OH group is converted into OTf with triflic anhydride); thus, phenolic compounds can be arylated by this method. Boronic esters, boranes or boronic acids can be used. Among the halides, the relative reactivity is I > OTf > Br > Cl.[65,7b]

The mechanism of the Suzuki reaction involes three steps. The first step is the oxidative addition of organic halides to Pd(0) to form organopalladium halides. In the second step, a transmetallation with the boronic acid provides a diorganopalladium complex, which undergoes reductive elimination and regeneration of the palladium catalyst. Different types of bases are used in this reaction, e.g. potassium carbonate, potassium phosphate and cesium carbonate, which enhance the rate of the transmetalation by increasing the nucleophilicity of the organoboran compound by formation of an organoborate.[64,66] Several catalysts are used for this reaction, e.g. $Pd(OAc)_2$ together with phosphine ligands (such as PPh_3, PCy_3, SPhos and XPhos), $Pd(PPh_3)_2Cl_2$, or Pd $(PPh_3)_4$.[67,36]

Suzuki-Miyaura reactions have prominent applications in various fields. For example, non-linear optical (NLO) materials were prepared.[68] Terphenyls can be synthesized which are structural elements in liquid crystals and fluorescent compounds.[69] Poly(2,7-carbazole) derivatives, which are active components in photovoltaic devices, have been also prepared by Suzuki-Miyaura reactions.[70]

Since last couple of years, Prof. Peter Langer's research group has studied site-selective Suzuki-Miyaura reactions of polyhalogenated heteroaromatic and aromatic compounds or their triflates. In this context, regioselective Suzuki-Miyaura reactions of 2,3-dibromobenzofuran (**a**),[71a] tribromopyrazoles (**b**),[71b] 2,4,5,6-tetrachloropyrimidine (**c**),[71c] 2,3,5-tribromo-N-methylpyrrole (**d**),[71d] 1,2-dibromo-3,5-difluorobenzene (**e**),[71e] 1,4-dibromo-2-fluorobenzene (**f**),[71f] 2,3,4-tribromothiophene (**g**),[71g] and 2,3,5-tribromothiophene (**h**)[71h] were reported (Figure **4.1**).

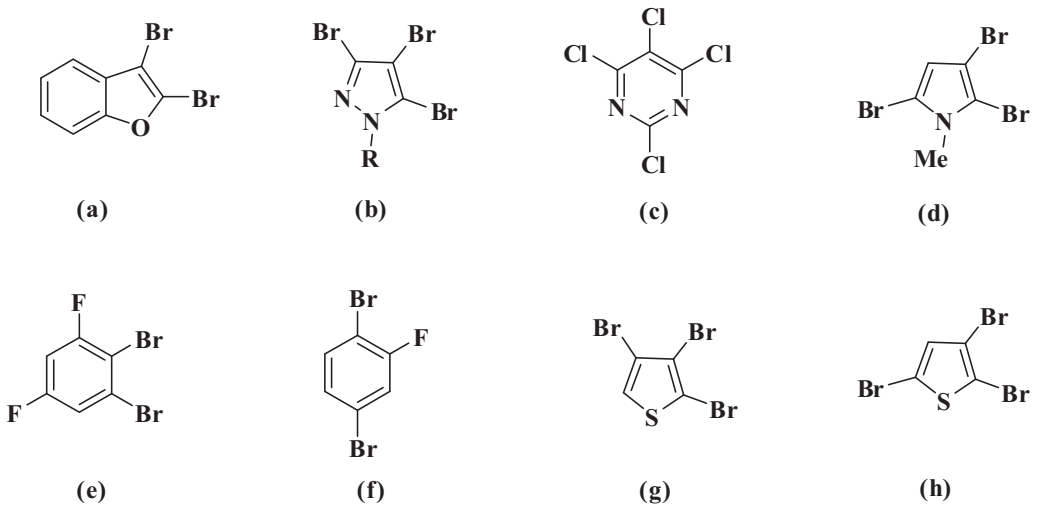


Figure 4.1: Suzuki reactions of vicinal halides studied in Prof. Langer's group

The Suzuki-Miyaura reaction also provided excellent results for dihydroxylated substrates. Their OH groups were converted into OTf groups by using triflic anhydride and subsequently the site-selctivity of Suzuki reactions was studied. The Langer group reported regioselective Suzuki-Miyaura cross coupling reactions of the bis(triflates) of dimethyl 4-fluoro-3,5-dihydroxphthalate (**i**),[72a] phenyl 1,4-dihydroxnaphthoate (**j**),[72b] methyl-2,5-dihydroxbenzoate (**k**),[72c] 3,4-dihydroxbenzoate (**l**),[72d] 2,4-bis(hydroxy)di- phenylsulfone (**m**)[72e] and 1,2-dihydroxyanthraquinone (**n**)[2f] (Figure **4.2**). All mentioned substrates proceeded with excellent site-selectivities.

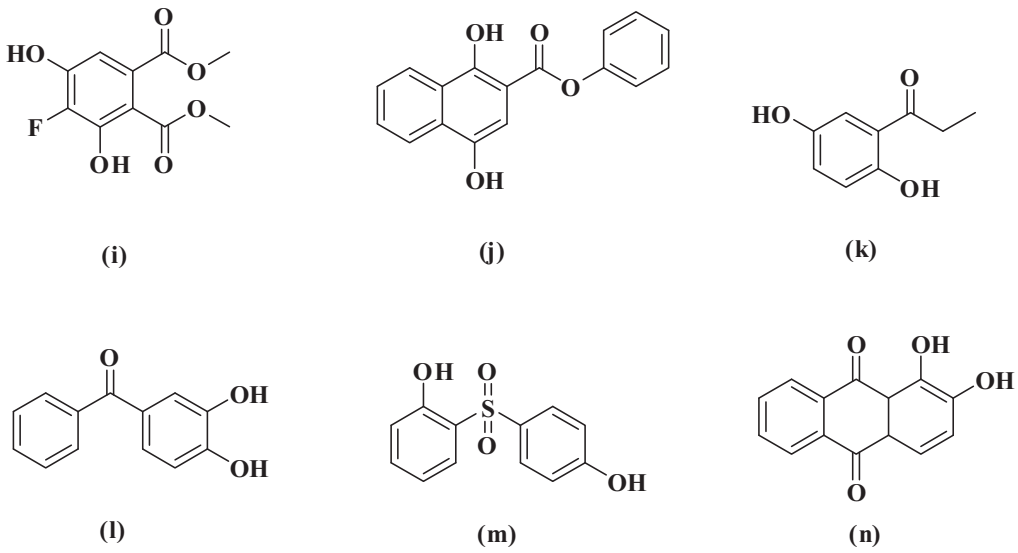


Figure 4.2: Suzuki Reaction Studies on Dihydroxy substrate in Prof. Langer's Group

4.2 Introduction to Trifluoromethyl-Substituted Di- and Terphenyls

The presence of fluorine in organic molecules is often associated with unusual reactivity, because of differences between physical and chemical properties of fluorinated compounds and their hydrogen analogues.[73a-c] The trifluoromethyl group is an important structural motif in many active pharmaceutical ingredients[73d-e] and have found numerous important applications in organic, materials, medicinal, and agricultural chemistry due to their unique physical, chemical, and biological properties.[73f-k] for example, *fluoxetine* (figure 4.3),[73l] is a potent anti-depresant widely used for improved sleep and alleviate anxiety. Moreover, Trifluoromethyl-substituted arenes and heterocycles are of considerable importance in agricultural and medicinal chemistry.[74] On the one hand, the CF_3 group has a strong electron-withdrawing effect while having similar size as a CH_3 group. Trifluoromethyl-substituted molecules show a high lipophilicity and, thus, excellent bioavailability. Due to similarity in the steric bulk and dissimilarity of the chemical behavior, CF_3 substituted compounds can act as anti-metabolites with respect to corresponding halogen-free natural products. In addition, the CF_3 group is chemically and biologically stable which is an important feature to avoid undesired metabolic transformations. The CF_3 group also plays an important role in the field of catalysis. This includes new substrates, fluorous reaction media, fluorinated ligands[75,76,7b] and fluorinated organocatalysts.[77]

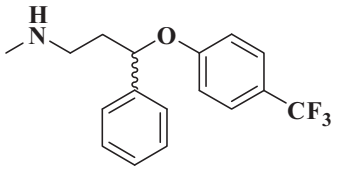


Figure 4.3: Fluoxetine- potent antidepressant.[73l]

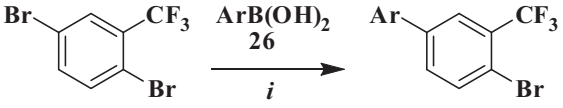
Trifluoromethyl-substituted arenes and heteroarenes have been prepared by reaction of aryl halides with trifluoromethylcopper.[73j] This strategy is limited by the unstable nature of the reagents and its failure for problematic substrates. Trifluoromethyl-substituted arenes have also been prepared by using CF_3-containing building blocks in cyclization reactions. Examples include cyclocondensations of enamines, Diels-Alder reactions, and formal [3+3] cyclizations.[78]

An alternative strategy relies on transition metal cross-coupling reactions of trifluoromethyl-substituted substrates. In recent years, site-selective palladium(0)-catalyzed cross-coupling reactions of polyhalogenated arenes and heteroarenes have been studied. It has been shown for various non-fluorinated substrates that such reactions provide a valuable tool for the rapid assembly of highly substituted arenes and heteroarenes.[79,80,46b,71c,d]

4.3 Results and discussion

Recently, Langer *et al*. reported the first examples of site-selective cross-coupling reactions of fluorinated substrates, such as 1,2-dibromo-3,5-difluorobenzene.[10] Site-selective reactions of CF_3-substituted substrates have, to the best of my knowledge, not been reported to date. Herein, I report the results in this field: the Suzuki-Miyaura (S-M) reaction of 1,4-dibromo-2-(trifluoromethyl)benzene with various arylboronic acids allowed for a convenient synthesis of various CF_3-substituted di- and terphenyls which are not readily available by other methods.

The Suzuki-Miyaura reaction of commercially available 1,4-dibromo-2-trifluoro methylbenzene (**25**) with arylboronic acids **26a-o** (1.0 equiv.) afforded the 4-aryl-1-bromo-2-trifluoromethylbenzenes **27a-o** in 79-94% yields (Scheme **4.1**, Table **4.1**). All reactions proceeded with very good site-selectivity in favour of position 4. Very good yields were obtained for products derived from both electron rich and poor arylboronic acids.



25 27a-o

Scheme 4.1: Synthesis of **27a-o**. *Conditions: i*, **26a-o** (1.0 equiv.), $Pd(PPh_3)_4$ (5 mol-%), K_2CO_3 (H_2O, 2 M), dioxane, 70 °C, 8 h

Table 4.1: Synthesis of 4-aryl-1-bromo-2-trifluoromethylbenzenes **27a-o**

26,27	*Ar*	*% (27)* [a]
a	C_6H_5	82
b	2-MeC_6H_4	87
c	2-ClC_6H_4	84
d	3-ClC_6H_4	86
e	3-(Vinyl)C_6H_4	84
f	4-EtC_6H_4	87
g	4-*t*BuC_6H_4	88
h	4-ClC_6H_4	83
i	4-FC_6H_4	80
j	2-Naphthyl	79
k	2,5-$(MeO)_2C_6H_3$	92
l	2,6-$(MeO)_2C_6H_3$	87
m	3,4-$(MeO)_2C_6H_3$	94
n	3,5-$Me_2C_6H_3$	83
o	2,3,4-$(MeO)_3C_6H_2$	82

[a] Yields of isolated products

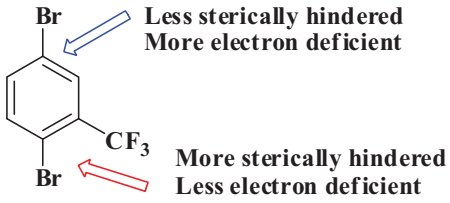
The best yields were obtained using exactly 1.0 equiv. of the arylboronic acid, $Pd(PPh_3)_4$ (5 mol-%) as the catalyst, and K_2CO_3 (2M aqueous solution) as the base (1,4-dioxane, 70 °C, 8 h) (Table **4.2**). The employment of other solvents or bases resulted in the formation of only trace amounts of product or no conversion at all. The increase of the temperature resulted in the formation of mixtures, due to the formation of significant amounts of terphenyls. The reaction time had only a small effect on the yields.

Table 4.2: Optimization of the synthesis of **27g** and **27m** ($Pd(PPh_3)_4$ was used as the catalyst)

entry	*solvent*	*base*	*T [°C]*	*t [h]*	*27m*	*27g*
1	dioxane	2M K_2CO_3	60	8	- [a]	- [a]
2	THF	2M K_2CO_3	60	8	- [a]	- [a]
3	DME	2M K_2CO_3	70	8	- [a]	- [a]
4	dioxane	3eq. Cs_2CO_3	70	8	traces	traces
5	dioxane	3 eq. K_3PO_4	70	8	traces	traces
6	toluene	3 eq. K_3PO_4	70	8	traces	traces
7	toluene	2M K_2CO_3	70	8	traces	traces
8	toluene	2M K_2CO_3	90	8	traces	traces
9	dioxane	2M K_2CO_3	90	6	- [b]	- [b]
10	dioxane	2M K_2CO_3	80	6	- [b]	- [b]
11	THF	2M K_2CO_3	75	6	- [c]	- [c]
12	dioxane	2M K_2CO_3	70	3	87%	82%
13	dioxane	2M K_2CO_3	70	8	94%	88%

[a] No conversion; [b] unseparable mixture of mono- and diarylated products; [c] unseparable mixture, mainly diarylated product

The first attack of palladium(0) catalyzed cross-coupling reactions generally occurs at the more electron deficient and sterically less hindered position.[77] Carbon atom C-4 is electronically more deficient sterically less hindered and than carbon C-1, due to its location *meta* to the CF_3 group (Scheme 4.4). Therefore, the first attack occurs at position 4 because of electronic and steric reasons.



Scheme 4.4: Possible explanation for the site-selectivity of cross-coupling reactions of **25**

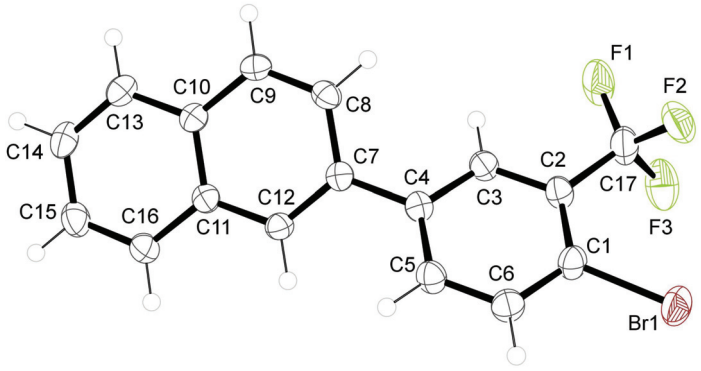


Figure 4.5: Crystal structure of **27j**

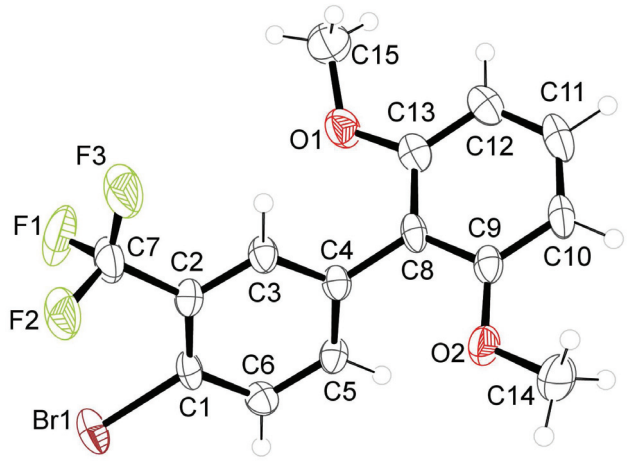
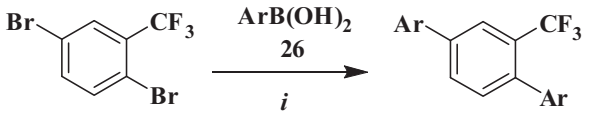


Figure 4.6: Crystal strucure of **27l**

The S-M reaction of **25** with 2.5 equiv. of various arylboronic acids **26** afforded the 2,5-diaryl-1-trifluoromethylbenzene derivatives **28a-m** in good yields (Scheme **4.2**, Table **4.3**). The reactions had to be carried out at 90 °C instead of 70 °C to ensure a complete conversion. Very good yields were again obtained for products derived from both electron rich and poor arylboronic acids.



25 **28a-m**

Scheme 4.2: Synthesis of 1,4-diarylbenzenes **28a-m**. *Conditions: i*, **26** (2.5 equiv.), $Pd(PPh_3)_4$ (5 mol-%), K_2CO_3 (H_2O, 2 M), dioxane, 90 °C, 8 h

Table 4.3: Synthesis of 2,5-diaryl-1-trifluoromethylbenzene **28a-m**

28	*26*	*Ar*	*% (28)* [a]
a	**a**	C_6H_5	84
b	**b**	2-MeC_6H_4	85
c	**p**	3-MeC_6H_4	86
d	**q**	3-$(CF_3)C_6H_4$	82
e	**r**	3-$(MeO)C_6H_4$	89
f	**s**	4-MeC_6H_4	85
g	**f**	4-EtC_6H_4	87
h	**t**	4-$(MeO)C_6H_4$	93
i	**u**	2,3-$(MeO)_2C_6H_3$	87
j	**k**	2,5-$(MeO)_2C_6H_3$	79
k	**m**	3,4-$(MeO)_2C_6H_3$	95
i	**n**	3,5-$Me_2C_6H_3$	87
m	**o**	2,3,4-$(MeO)_3C_6H_2$	91

[a] Yields of isolated products

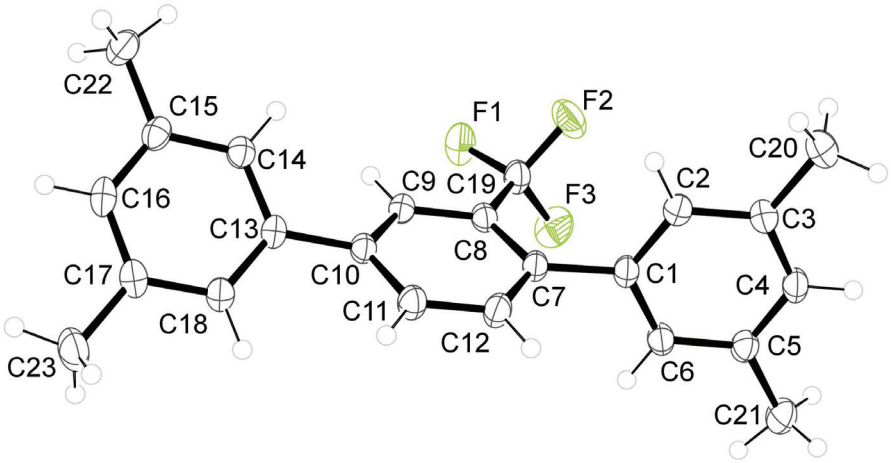


Figure 4.7: Crystal structure of **28i**

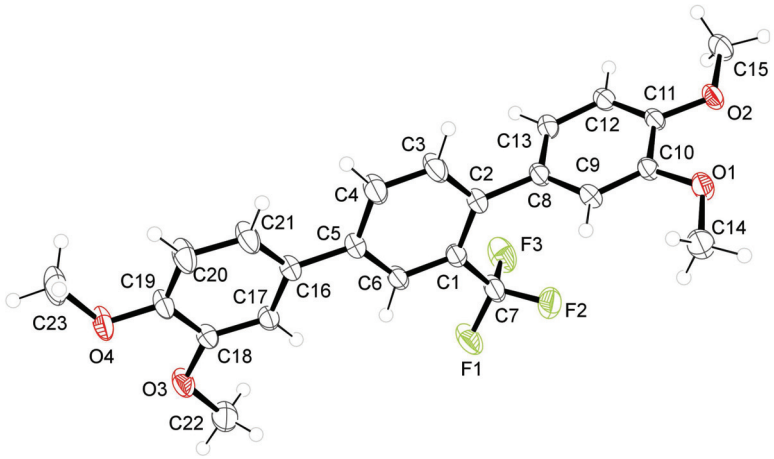
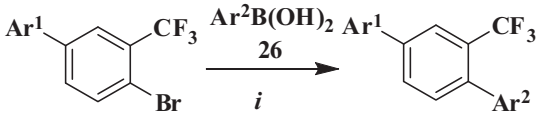


Figure 4.8: Crystal structure of **28m**

The bromide group of biaryls **27** easily undergo S-M reactions. The reaction of **27f,j,m** with arylboronic acids afforded terphenyls **29a-d** in high yields (Scheme **4.3**, Table **4.4**). A one-pot synthesis of **29a-d** starting with **25** also proved to be possible (sequential addition of the two different boronic acids). However, the yields proved to be lower as compared to the stepwise procedure. Therefore, this strategy was not further studied.



27f,j,m **29a-d**

Scheme 4.3: Synthesis of **29a-d**. *Conditions: i*, **26i,m,n** (1.0 equiv.), $Pd(PPh_3)_4$ (5 mol-%), K_2CO_3 (H_2O, 2 M), dioxane, 80 °C, 8 h

Table 4.4: Synthesis of terphenyls **29a-d**

29	*27*	*26*	*Ar^1*	*Ar^2*	*% (29)[a]*
a	**f**	**m**	4-EtC_6H_4	3,4-$(OMe)_2C_6H_4$	88
b	**j**	**m**	2-Naph	3,4-$(OMe)_2C_6H_4$	85
c	**m**	**i**	3,4-$(OMe)_2C_6H_4$	4-FC_6H_4	80
d	**m**	**n**	3,4-$(OMe)_2C_6H_4$	3,5-$(Me)_2C_6H_4$	86

[a] Yields of isolated products

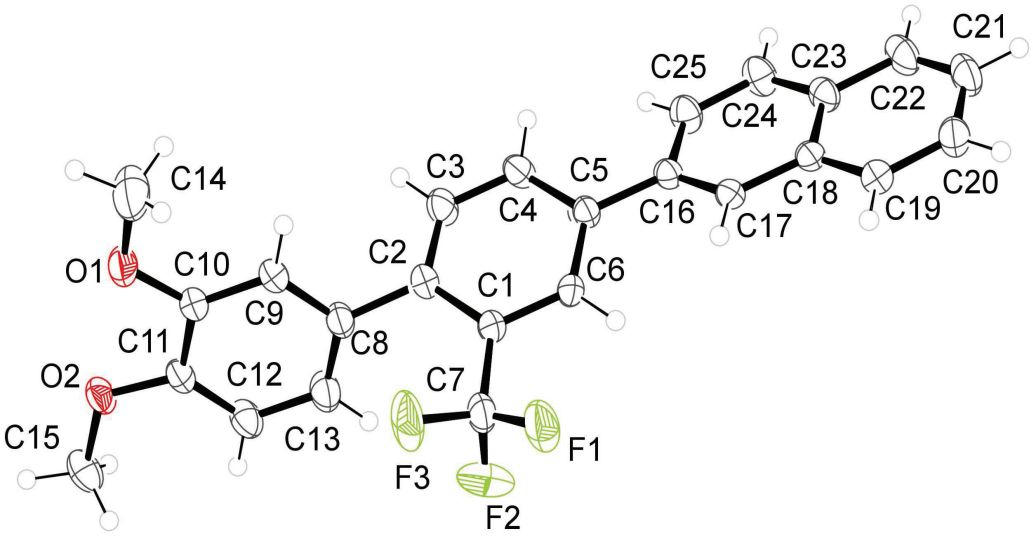


Figure 4.9: Crystal structure of **29b**

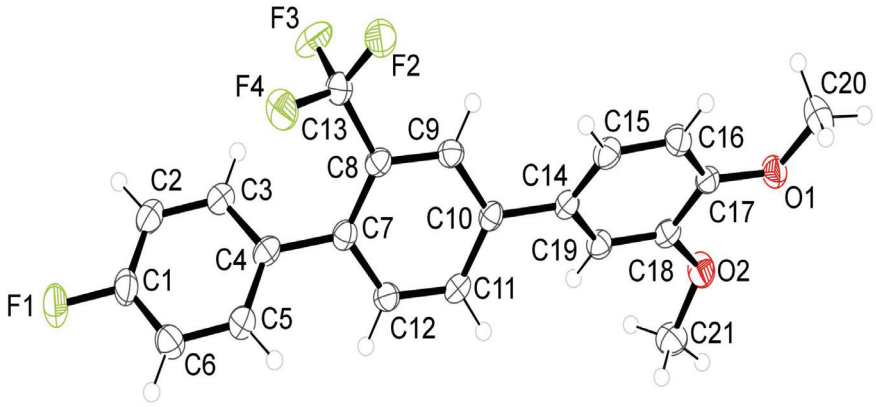


Figure 4.10: Crystal structure of **29c**

The structures of all the compounds were confirmed by spectroscopic methods. The structures of **27j, 27l, 28i, 28m, 29b** and **29c** were independently confirmed by X-ray crystal structure analyses (Figures **4.5-4.10** repectively). In case of both biaryls the two aryl groups are twisted out of plane due to steric reasons. Similarly, in case of terphenyls all three aryl groups are in different planes.

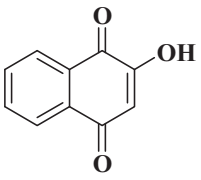
4.4 Conclusion

In conclusion, I have reported site-selective Suzuki-Miyaura reactions of 1,4-dibromo-2-trifluoromethyl-benzene. These reactions provide a convenient and site-selective approach to trifluoromethyl-substituted di- and terphenyls which are not readily available by other methods.

Synthesis of Tetraaryl-*p*-benzoquinones by Suzuki Cross-Coupling Reactions of Tetrabromo-*p*-benzo-quinone

5.1 Introduction

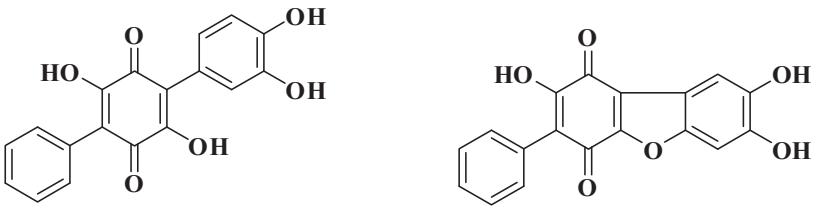
Quinones are an important class of naturally occurring compounds that are found in plants, fungi, and bacteria. The privileged quinone moiety possesses electron and proton transfer properties which are essential to nearly each and every living organism.[81] This class pervades the realms of chemistry, material science, nanotechnology, and medicine.[82] They are also found in several natural products,[82b] including sesquiterpenes,[83] the kinamycins,[84] and terphenylquinones.[85] Additionally, there are several drugs and therapeutic leads that contain the quinone subunit.[86] Arylated quinones possess unique visual and electronic properties that make them useful in photosynthesis[87] and appealing structures to the dye industry,[88] for example, Lawsone (Figure **5.1**), also known as hennotannic acid, is a quinoid moiety, found in the leaves of henna plant *(Lawsonia inermis)*. The henna leaves are in human use as hair and skin dye since 5000 years and it is reported that the content of lawsone makes henna a substantive dye .[88l]



Lawsone

Figure 5.1: Lawsone

Quinones also play a key role in cell respiration.[89] *p*-Dihydrobenzoquinones[90,91] and *p*-benzoquinones[90,92,93] play an important role in medicinal chemistry and occur in a number of pharmacologically important natural products, such as sorrentanone and α-tocopherolquinone. In addition, they have found many technical applications and also represent important synthetic building blocks, for example, Terphenylquinones (Figure **5.2**), have been reported to exhibit significant activity against human src protein tyrosine kinase.[93l]



Terphenylquinones

Figure 5.2: Terphenylquinones-isolated from natural sources

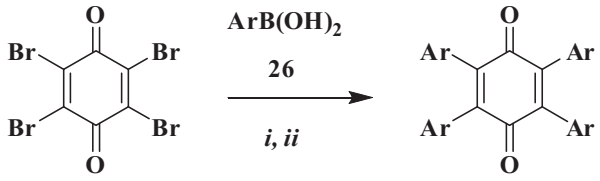
Tetrabromo- and tetrachlorobenzoquinone represent versatile synthetic building blocks. Known transformations include, for example, reactions with amines,[94] thiols,[95] Grignard reagents,[96] malodinitrile,[97] alkyne carbanions,[98] indole,[99] and cyclizations with *S,S*-, *N,S*-, and *N,O*-dinucleophiles,[100] and [4+2] cycloadditions.[101] Tetraaryl-*p*-benzoquinones have been previously prepared by reaction of phenyldiazonium salts with tetrabromoquinone[102] and by oxidation of 2,3,5,6-tetraarylphenols.[103] The base-mediated reaction of tetrachloro-*p*-benzoquinone with 2,6-di-(*tert*-butyl)phenol has been reported to give the corresponding *p*-benzoquinone.[104] However, these methods are not general.

Transition metal-catalyzed cross-coupling reactions of polyhalogenated molecules are of considerable current interest.[79a] Recently, Langer *et al*. reported the synthesis of aryl-substituted thiophenes,[105] pyrroles,[80a] and selenophenes[80b] based on regioselective Suzuki reactions of tetrabromothiophene, tetrabromo-*N*-methylpyrrole, and tetrabromoselenophene, respectively. Transition metal-catalyzed cross-coupling reactions of tetrabromo- and tetrachloro-*p*-benzoquinone have, to the best of my knowledge, not been reported to date. Herein, I report the synthesis of tetraaryl-*p*-benzoquinones by Suzuki reactions of tetrabromo-*p*-benzoquinone with arylboronic acids.

5.2 Results and discussion

Our starting point was to find suitable conditions for the synthesis of tetraphenyl-*p*-benzoquinone (**31a**) by Suzuki reaction of tetrabromo-*p*-benzoquinone (**30**) with arylboronic acid (**26a**, 4.0 equiv.) (Scheme **5.1**, Table **5.1**). The reaction of **30** with **26a** in the presence of $Pd(PPh_3)_4$ (5 mol-%) and K_2CO_3 (THF/H_2O, 90 °C, 12 h) resulted in the formation of an inseparable 1:1 mixture of **31a** and of 2,3,5,6-tetraphenyl-*p*-dihydrobenzoquinone in higher yield (entry 12 Table **5.2**). Treatment of this mixture with DDQ resulted in the formation of pure **31a** in 70% overall yield (based on **30**). The yield could be further increased (to 73%) when 10 mol-% of the catalyst was employed (entry 14 Table **5.2**). The increase of the amount of boronic acid (6.0 equiv.) did not result in an increase of the yield, however, the use of 2.0 instead of 4.0 equiv. of **26a** afforded **31a** in low yield. Change in the reaction time have not much effect on an increase of yield. Reaction did not occurred below 70 °C (entries 19 and 20, Table **5.2**), the best yield can be obtained at 90 °C while further increasing the temperature lowers the yield. The use of K_3PO_4 (dioxane/H_2O) also did not result in an increase of the yield. The best yield were obtained for K_2CO_3 rather than Cs_2CO_3 and K_3PO_4. The formation of a diaryldibromo-*p*-benzoquinone was not observed at all instead of using least amount of **26a**, this may be better explained due to all the four substitution positions being symmetrical. Although, the use of tetrachloro- instead of tetrabromo-*p*-benzoquinone resulted in successful reactions but the yield of reactions was not discouraging-better explanation being that bromine is a better leaving group than chlorine.

Recently, Li and Wang reported[106] that triethanolamine represents an efficient and reusable combined base, ligand, and solvent for $Pd(OAc)_2$-catalyzed reactions (entries 1 and 2, Table **5.2**). However, its application to the reaction of **26a** and **26s** with **30** proved to be unsuccessful. The use of $Pd(OAc)_2$ in the presence of **X-Phos** (entries 3 and 4, Table **5.2**) or **S-Phos** (entries 5-10, Table 2), biaryl monophosphine ligands developed by Buchwald and coworkers,[47] and subsequent oxidation (DDQ) resulted in the formation of **31a**, **31b** and **31g**, but overall yields were not better than those obtained by using $Pd(PPh_3)_4$, however, In case of **S-Phos**, the yield could be increased when the double amount of catalyst and ligand was used (entry 10, Table **5.2**). The synthesis of tetra(4-tolyl)-*p*-benzoquinone (**31b**) tetra(4-methoxyphenyl)-*p*-benzoquinone (**31g**) was also optimized and a similar trend was observed.



30 **31a-s**

Scheme 5.1: Synthesis of tetraaryl-*p*-benzoquinones **31a-s**. Conditions: *i*, **26** (4.0 eq.), $Pd(PPh_3)_4$ (5 mol-%), K_2CO_3 (THF/H_2O, 90 °C, 12 h; *ii*, DDQ, benzene, 3 h, 20 °C.

Table 5.1: Synthesis of tetraaryl-*p*-benzoquinones **31a-s.**

31	*26*	*Ar*	*% (31)* [a]
a	**a**	Ph	70
b	**s**	4-MeC_6H_4	75
c	**f**	4-EtC_6H_4	80
d	**g**	4-*t*BuC_6H_4	78
e	**v**	4-(vinyl)C_6H_4	56
f	**w**	4-$(F_3C)C_6H_4$	51
g	**t**	4-$(MeO)C_6H_4$	92
h	**x**	4-$(EtO)C_6H_4$	89
i	**y**	4-$(F_3CO)C_6H_4$	81
j	**z**	4-$(MeS)C_6H_4$	86
k	**aa**	4-BrC_6H_4	73
l	**d**	3-ClC_6H_4	75
m	**ab**	3-FC_6H_4	72
n	**q**	3-$(F_3C)C_6H_4$	64
o	**r**	3-$(MeO)C_6H_4$	87
p	**e**	3-(vinyl)C_6H_4	62
q	**ac**	2-FC_6H_4	58
r	**n**	3,5-$Me_2C_6H_3$	73
s	**ad**	3,4-$Me_2C_6H_3$	79

[a] Yield of isolated products

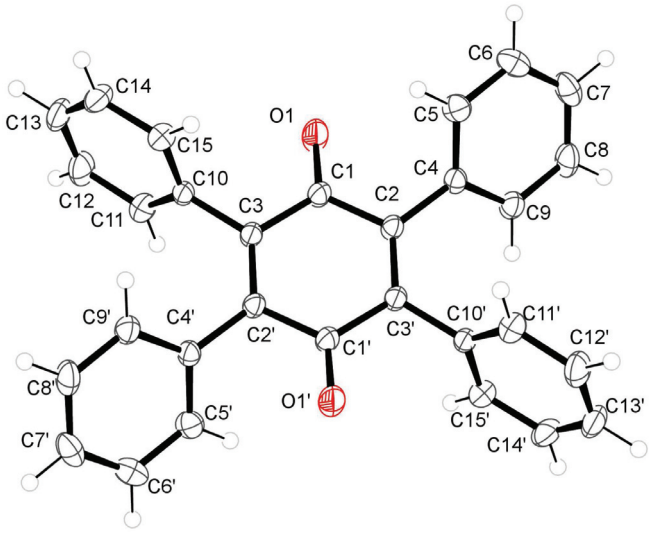


Figure 5.3: Crystal structure of **31a.**

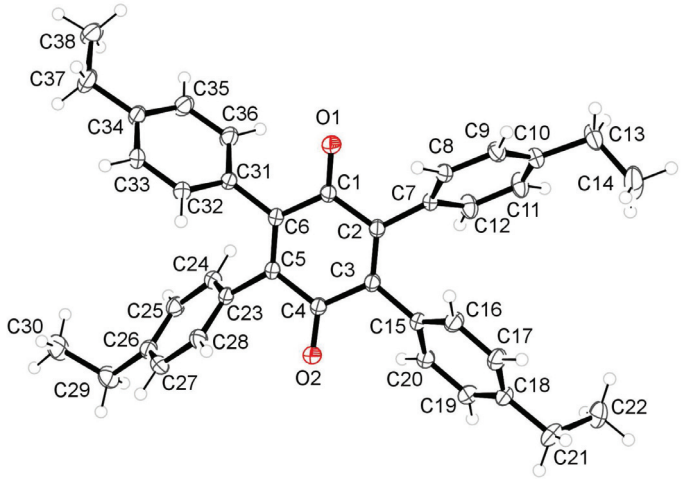


Figure 5.4: Crystal structure of **31c**

Table 5.2: Optimization of the synthesis of tetraaryl-*p*-benzoquinones **31a, 31b** and **31g.**

entry	*catalyst*	*solvent*	*base*	*T [°C]*	*t [h]*	*% (31a)*[a]	*% (31b)*[a]	*% (31g)*[a]
1	$N(CH_2CH_2OH)_3$/ $Pd(OAc)_2$ (5mol-%)	dioxane	2M K_2CO_3	90	36	-[c]	-[c]	-[b]
2	$N(CH_2CH_2OH)_3$/ $Pd(OAc)_2$ (5mol-%)	THF	2M K_2CO_3	90	36	-[c]	-[c]	-[b]
3	**L_2** (10 mol-%)/ $Pd(OAc)_2$ (5 mol-%)	THF	2M K_2CO_3	90	12	30	25	32
4	**L_2** (10 mol-%)/ $Pd(OAc)_2$ (5 mol-%)	dioxane	2M K_2CO_3	90	12	35	30	40
5	**L_1** (10 mol-%)/ $Pd(OAc)_2$ (5 mol-%)	THF	2M K_2CO_3	90	12	45	50	-[b]
6	**L_1** (10 mol-%)/ $Pd(OAc)_2$ (5 mol-%)	THF	3 eq. K_3PO_4	90	12	-[b]	32	40
7	**L_1** (10 mol-%)/ $Pd(OAc)_2$ (5 mol-%)	dioxane	3 eq. K_3PO_4	90	12	20	-[b]	35
8	**L_1** (10 mol-%)/ $Pd(OAc)_2$ (5 mol-%)	dioxane	3M K_3PO_4	90	12	-[b]	25	30
9	**L_1** (10 mol-%)/ $Pd(OAc)_2$ (5 mol-%)	dioxane	3M K_3PO_4	110	12	-[b]	28	32
10	**L_1** (20 mol-%)/ $Pd(OAc)_2$(10 mol-%)	THF	2M K_2CO_3	90	12	50	53	-[b]
11	$Pd(PPh_3)_4$ (5 mol-%)	THF	2M K_2CO_3	90	8	65	70	88
12	$Pd(PPh_3)_4$ (5 mol-%)	THF	2M K_2CO_3	90	12	70	75	92
13	$Pd(PPh_3)_4$ (5 mol-%)	dioxane	2M K_2CO_3	90	12	60	-[b]	80
14	$Pd(PPh_3)_4$ (10 mol-%)	THF	2M K_2CO_3	90	12	73	80	93
15	$Pd(PPh_3)_4$ (5 mol-%)	THF	3eq. Cs_2CO_3	90	12	-[b]	-[b]	68
16	$Pd(PPh_3)_4$ (5 mol-%)	Toluene	2M K_2CO_3	90	12	-[b]	-[b]	75
17	$Pd(PPh_3)_4$ (5 mol-%)	Toluene	2M K_2CO_3	110	12	-[b]	-[b]	77

18	$Pd(PPh_3)_4$ (5 mol-%)	Dioxane	2M K_2CO_3	110	12	- [b]	- [b]	70
19	$Pd(PPh_3)_4$ (5 mol-%)	THF	2M K_2CO_3	60	12	- [c]	- [b]	- [c]
20	$Pd(PPh_3)_4$ (5 mol-%)	THF	2M K_2CO_3	70	12	60	- [b]	80

[a] Yields of isolated products; [b] Reaction was not carried out; [c] No conversion.

Following the best optimization trends ($Pd(PPh_3)_4$ (5 mol-%), K_2CO_3 (THF/H_2O, 90 °C, 12 h), tetraarylbenzoquinones **31a-s** were prepared, in 51-92 % yields (Table **5.1**). Both electron-poor and electron-rich arylboronic acids could be successfully employed. Better yields were obtained for electron-rich arylboronic acids (for example, entries 7 and 8, Table **5.1**) than electron-poor arylboronic acids (for example, entries 6 and 17, Table **5.1**). The yields dropped for arylboronic acids which are sterically hindered or contain electron-withdrawing substituents.

All the compounds were characterized by spectroscopic methods. The structures of **31a**, **31c**, **31i** and **31q** were independently confirmed by X-ray crystal structure analyses (Figures **5.3-5.6** respectively). It is noteworthy that no intramolecular hydrogen bonding O–H···O was observed in case of **31a**, **31c** and **31i** at all, may be due to long distance or my be very weak hydrogen bonding exist due to symmetrical hydrogen atoms around oxygen. Moreover, all four aryl groups attached to quinone moiety are twisted out of plane in all cases.

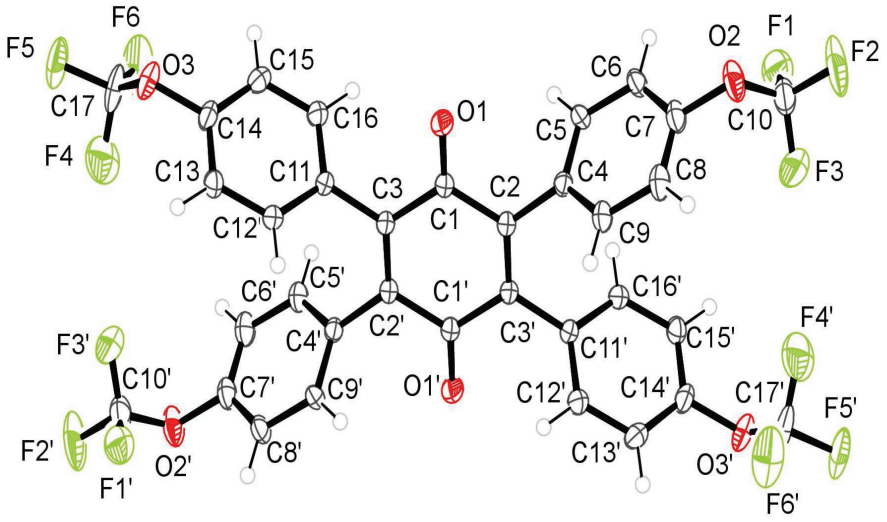


Figure 5.5: Crystal structure of **31i**

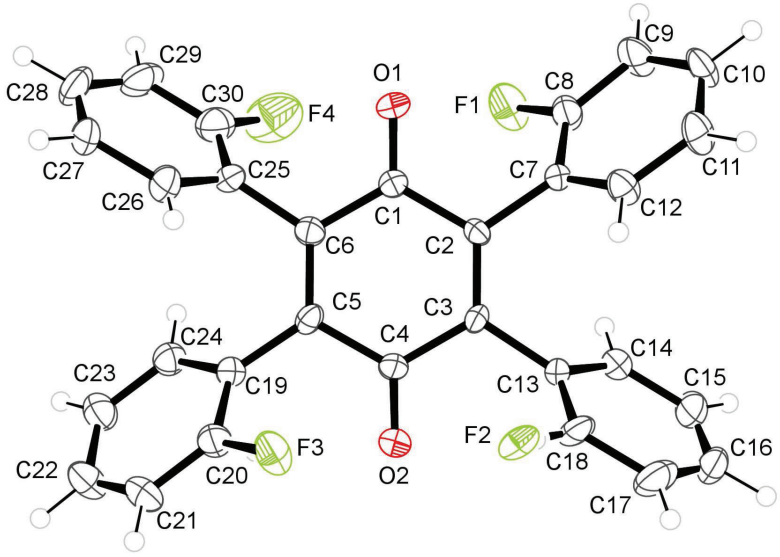


Figure 5.6: Crystal structure of **31q**

UV/Vis- and fluorescence spectroscopy measurements were carried out for the cyclohexa-2,5-diene-1,4-diones **(31)**. The UV/Vis and fluorescence spectra of 2,3,5,6-tetrakis(4-(trifluoromethyl)phenyl)cyclohexa-2,5-diene-1,4-dione **(31f)** is shown in figure **5.7**. The absorption spectrum for compound **31f** shows two transitions at 235 nm (absorption maximum) and 339 nm. The measured emission spectrum (excitation wavelength λ_{ex} = 350 nm) shows a small band at 353

nm and a strong band at 408 nm **5** (Figure **5.7**). All compounds of this cyclohexa-2,5-diene-1,4-dione product type showed similar absorption/emission maxima and transitions **(table 5.3)**.

The Stokes shift was calculated as: Stokes shift = $\lambda_{em,\,max} - \lambda_{abs,max}$

As expected the change concerning the Stoke shifts depends on the substitution pattern. The largest value was determined for compound **31h** (209 nm) (Table **5.1** and **5.3**) when the cyclohexa-2,5-diene-1,4-dione moiety was substituted by para-ethoxyphenylgroups.

Table 5.3: Assigned transitions of cyclohexa-2,5-diene-1,4-dione derivates (**31**)

entry	$\lambda 1_{abs}$ *[nm]*	*log*ε	$\lambda 4_{em}$ *[nm]*	*Stokes Shift [nm]*
31d	239	4.95	395	156
31e	262	5.15	425	163
31m	231	4.97	410	179
31r	227	4.75	395	168
31f	235	5.22	410	175
31n	233	5.29	410	177
31h	251	5.07	460	209
31i	233	5.18	420	187
31q	230	5.24	400	170
31k	242	5.22	420	178
31l	228	4.96	420	192

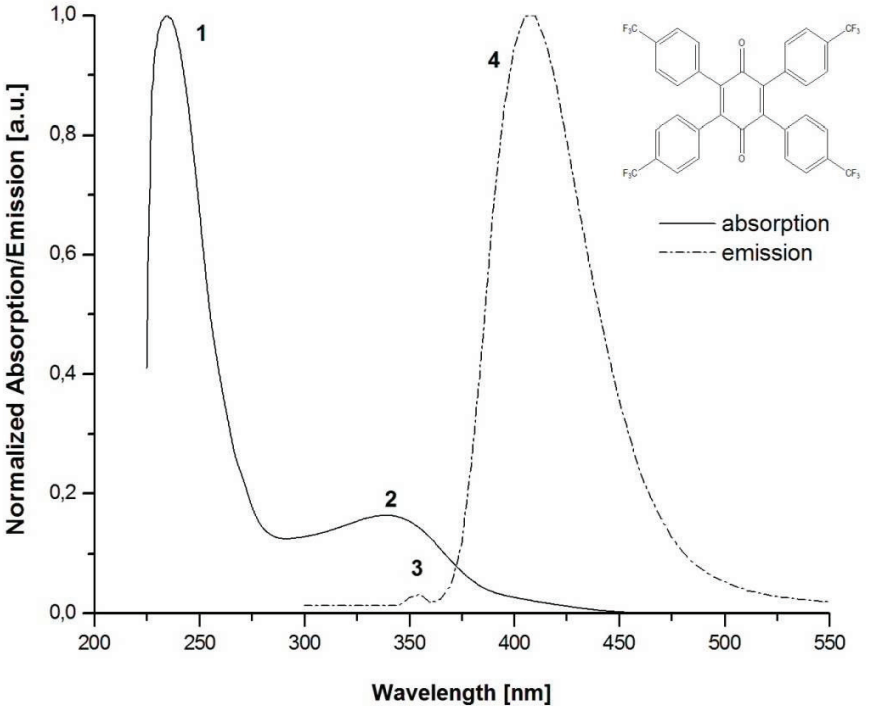


Figure 5.7: Absorption and Emission spectra of compound **31f**

5.3 Conclusion

In conclusion, I have reported the synthesis of tetraaryl-*p*-benzoquinones by Suzuki cross-coupling reactions of tetrabromo-*p*-benzoquinone.

6 *Abstract*

Transition metal catalyzed reactions constitute one of the most powerful and direct approaches for the synthesis of organic molecules. This thesis focuses on the development of C-C bond forming reactions using transition metal catalysis.

The synthesis of salicylates and 3-aryl-3,4-dihydroisocoumarins was achieved by $TiCl_4$-mediated regioselective chelation-controlled cyclizations of 1,3-bis(silyl enol ethers) with 1-hydroxy-5-silyloxy-4-en-3-ones. Sterically encumbered and functionalized biaryls were prepared based on $TiCl_4$-mediated regioselective [3+3] cyclocondensation reactions of 1,3-bis(silyl enol ethers) with 2-aryl-3-silyloxy-2-en-1-ones.

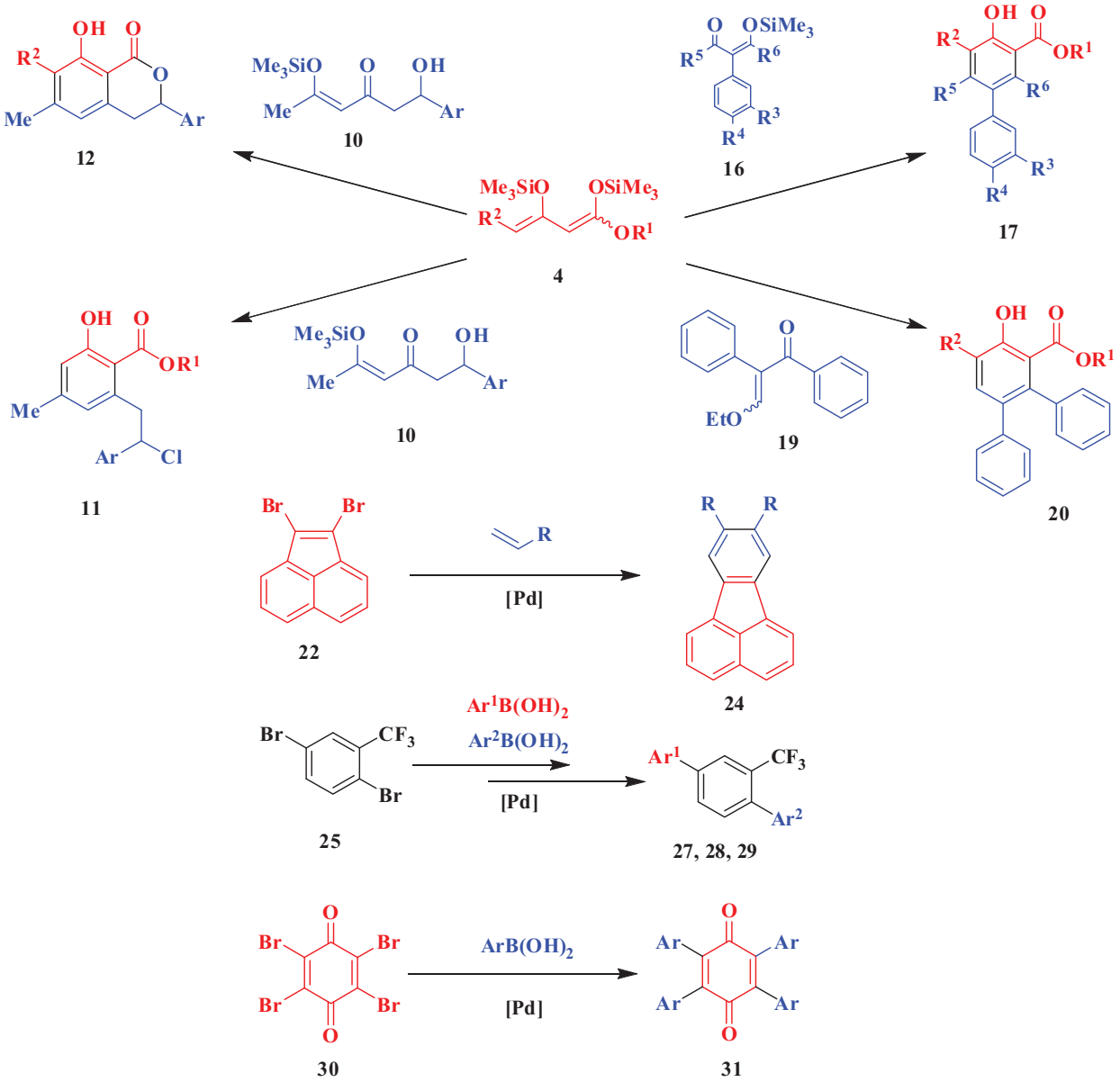
The palladium(0)-catalyzed Heck cross coupling reactions of 1,2-dibromoacenaphthylene provided functionalized fluoranthenes by domino twofold Heck / 6π-electrocyclization reactions. Palladium(0)-catalyzed Suzuki-Miyaura cross coupling reactions of 1,4-dibromo-2-(trifluoromethyl)benzene with different arylboronic acids afforded 4-aryl-1-bromo-2-(trifluoromethyl)benzenes, 2,5-diaryl-1-(trifluoromethyl)benzene and terphenyls. Tetraaryl-*p*-benzoquinones were synthesized by palladium(0)-catalyzed Suzuki-Miyaura cross coupling reactions of different boronic acids with tetrabromo-*p*-benzoquinone.

Übergangsmetallkatalysierte Reaktionen sind ein wichtiges Werkzeug bei der Synthese von organischen Molekülen. Der Schwerpunkt dieser Doktorarbeit liegt auf der Entwicklung von C-C-Knüpfungsreaktionen unter Anwendung der Übergangsmetallkatalyse.

Die Synthese von Salicylaten und 3-Aryl-3,4-dihydroisocoumarinen gelang durch $TiCl_4$-vermittelte regioselektive chelatkontrollierte Cyclisierung von 1,3-Bis(silylenolethern) mit 1-Hydroxy-5-silyloxy-4-en-3-onen. Außerdem wurden durch $TiCl_4$-vermittelte regioselektive [3+3]-Cyclokondensationsreaktionen von 1,3-Bis(silylenolethern) mit 2-Aryl-3-silyloxy-2-en-1-onen sterisch anspruchsvolle und funktionalisierte Biaryle dargestellt.

Palladium(0)-katalysierte Heck-Kreuzkupplungsreaktionen an 1,2-Dibromacenaphthylen ergaben funktionalisierte Fluoranthene durch zweifache Domino-Heck/6π-Electrocyclisierung. Die Palladium(0)-katalysierte Suzuki-Miyaura-Kreuzkupplung von 1,4-Dibrom-2-

(trifluormethyl)benzen mit verschiedenen Arylboronsäuren lieferte 4-Aryl-1-brom-2-(trifluormethyl)benzenderivate, 2,5-Diaryl-1-(trifluormethyl)benzenderivate und Terphenyle. Tetraaryl-*p*-benzochinone wurden durch Palladium(0)-katalysierte Suzuki-Miyaura-Kreuzkupplung von Tetrabrom-*p*-benzochinon mit verschiedenen Boronsäuren dargestellt.



General scheme: Transition metal catalyzed reactions developed in the present thesis.

7 *Experimental Section*

7.1 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 = 7.26 ppm for ($CDCl_3$); Characterization of the signal fragmen- tations: s = singlet, d = doublet, dd = double of doublet, dt = double of triplet = triplet, q = quartet, m = multiplet, br = broadly. All coupling constants are indicated as (*J*). 2D NMR techniques (NOESY, COSY, HMQC, and HMBC) were used for the confirmation of structure.

^{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 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.

^{19}F-NMR Spectroscopy:

Bruker: ARX 300, (282 MHz), δ = 0.00 ppm for Tetramethylsilane.

Mass Spectroscopy:

AMD MS40, Varian MAT CH 7, MAT 731 (EI, 70 eV), Intecta AMD 402 (EI, 70 eV and CI), Finnigan MAT 95 (CI, 200 eV).

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; Peaks are given following assignments: w = weak, m = medium, s = strong, br = broad.

Elemental Analysis:

LECO CHNS-932, Thermoquest Flash EA 1112.

X-ray crystal structure analysis:

Crystallographic data were collected on a Bruker X8Apex, Diffractometer with CCD-Kamera (MoKa und Graphit Monochromator, = 0.71073 Å). The structures were solved by direct methods using SHELXS-97 and refined against *F*2 on all data by full matrix least-squares with SHELXL-97.

Melting points:

Micro heating table HMK 67/1825 Kuestner (Büchi apparatus).

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.

Thin Layer Chromatography (TLC):

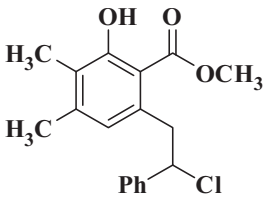
Merck DC finished foils silica gel 60 F_{254} on aluminum foil and Macherey finished foils Alugram® Sil G/UV_{254}. Detection under UV light with 254 nm and/or 366 nm without dipping reagent, as well as with anisaldehyde sulfuric acid reagent (1 mL anisaldehyde consisting in 100 mL stock solution of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

7.2 Synthesis of functionalized 2-(2-chloro-2-phenylethyl)-6-hydroxybenzoate and 3-aryl-3,4-dihydroisocoumarins by regioselective domino ′[3+3] cyclization / lactonization′ reactions of 1,3-bis-(silyloxy)-1,3-butadienes with 1-hydroxy-5-silyloxy-4-en-3-ones.

General procedure for the synthesis of functionalized 2-(2-chloro-2-phenylethyl)-6-hydroxybenzoate (11a,v):

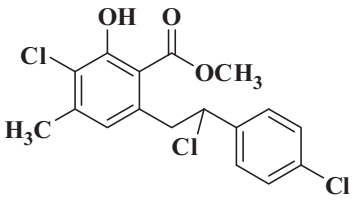
To a CH_2Cl_2 solution (2 mL / 1.0 mmol of ***5***) of ***4*** (1.0 equiv.) was added ***10*** (1.0 equiv.) and subsequently $TiCl_4$ (1.0 equiv.) at −78 °C. The temperature of the solution was allowed to warm to 20 °C during 14 h with stirring. To the solution was added hydrochloric acid (10%, 10 mL) and the organic and the aqueous layers were separated. The later was extracted with CH_2Cl_2 (3 x 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, *n*-heptane / EtOAc) to give product **functionalized 2-(2-chloro-2-phenylethyl)-6-hydroxybenzoate *(11)*** (28-35% yield).

Methyl 6-(2-chloro-2-phenylethyl)-2-hydroxy-3,4-dimethylbenzoate (11a):



Starting with 1,3-bis(silyl enol ether), ***5d*** (600 mg, 2.18 mmol), 1-Hydroxy-1-phenyl-5-(trimethylsilyloxy)hex-4-en-3-one, ***10a*** (608 mg, 2.18 mmol) and $TiCl_4$ (0.24 mL, 2.18 mmol), ***11a*** was obtained as a light yellow oil (243 mg, 35%). ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 2.14 (s, 3H, CH_3), 2.19 (s, 3H, CH_3), 3.58 (dd, 2H, *J* = 7.6, 5.6 Hz, CH_2), 3.93 (s, 3H, OCH_3), 5.01 (dd, *J* = 7.6, 5.7 Hz, 1H, CH), 6.42 (s, 1H, H_{Ar}), 7.31-7.35 (m, 5H, Ph), 11.61 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 11.5, 20.3 (CH_3), 46.7 (CH_2), 52.3 (OCH_3), 64.3 (CH), 108.7, 124.1 (C_{Ar}), 126.0 (CH_{Ar}), 126.9 ($3CH_{Ar}$), 128.5 ($2CH_{Ar}$), 136.0, 141.8, 143.4, 161.0 (C_{Ar}), 171.9 (C=O); IR (KBr): $\tilde{\nu}$ = 2927 (m), 2862 (w), 1670 (s), 1629 (m), 1435 (w), 1220 (s), 1126 (m), 1041 (w), 970 (s), 901 (s), 810 (s) cm^{-1}; GC-MS (EI, 70eV): m/z (%): 318 (M^+, ^{35}Cl, 33), 282 (10), 251 (43), 250 (76), 222 (10), 194 (14), 193 (100), 179 (10), 178 (14), 161 (11), 133 (28), 125 (18), 91 (10), 77 (10); HRMS (EI): calcd. for $C_{18}H_{19}ClO_3$ $[M]^+$: 318.101720; Found: 318.101963.

Methyl3-chloro-6-(2-chloro-2-(4-chlorophenyl)ethyl)-2-hydroxy-4-methylbenzoate (11v):



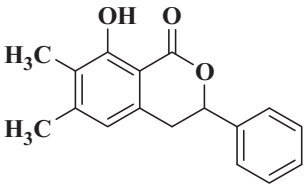
Starting with 1,3-bis(silyl enol ether), ***4k*** (600 mg, 2.03 mmol), 1-(4-chlorophenyl)-1-hydroxy-5-(trimethylsilyloxy)hex-4-en-3-one, ***10g*** (636 mg, 2.03 mmol) and $TiCl_4$ (0.22 mL, 2.03 mmol), ***11v*** was obtained as an orange solid (212 mg, 28 %), m.p = 135-137 ^{o}C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 2.25 (s, 3H, CH_3), 3.49 (dd, 2H, J = 7.4, 4.1 Hz, CH_2), 3.90 (s, 3H, OCH_3), 4.89 (dd, 1H, J = 7.4, 4.2 Hz, CH), 6.40 (s, 1H, H_{Ar}), 7.19 (d, 2H, J = 8.5 Hz, $2H_{Ar}$), 7.25 (d, 2H, J = 8.5 Hz, $2H_{Ar}$), 11.76 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 20.6 (CH_3), 46.4 (CH_2), 52.8 (OCH_3), 62.8 (CH), 110.4, 121.9 (C_{Ar}), 126.0 (CH_{Ar}), 128.3 ($2CH_{Ar}$), 128.7 ($2CH_{Ar}$), 134.2, 136.8, 139.8, 143.1, 158.5 (C_{Ar}), 171.0 (C=O); IR (KBr): $\tilde{\nu}$ = 2953 (w), 2848 (w), 1728 (w), 1655 (s), 1607 (m), 1549 (m), 1492 (m), 1434 (s), 1391(m), 1307 (m), 1263 (s), 1213 (s), 1091 (m), 1065 (m), 1013 (m), 956 (m), 870 (m), 804 (s), 769 (m), 722 (m), 651 (m), 579 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 372 (M^+, ^{35}Cl, 16), 338 (10), 336 (13), 307 (19), 306 (32), 305 (27), 304 (40), 215 (32), 214 (12), 213 (100), 178 (12), 161 (17), 159 (27), 153 (16); HRMS (EI): calcd. for $C_{17}H_{15}Cl_3O_3$ $[M]^+$: 372.008130; Found: 372.007884.

Typical procedure for the synthesis of 3-Aryl-3,4-dihydroisocoumarins (12a-w):

To a THF solution of **11** (190 mg, 0.62 mmol) silica gel (Merck silica gel 60, 0.063-0.200 mm, 70-230 mesh, 1.5 g) was added and the mixture was stirred at room temperature for 6-14 h. After completion of the reaction (tlc control), THF was removed in *vacuo*. The residue was purified by chromatography (silica gel, heptane / ethyl acetate) to give **12**.

In majority of cases, 3-aryl-3,4-dihydroisocoumarins (**12)**, were formed by [3+3] cyclization to give 2-(2-chloro-2-phenylethyl)-6-hydroxybenzoate (**11),** which subsequently hydrolyzed and underwent a lactonization during the aqueous work-up or silica gel chromatography.

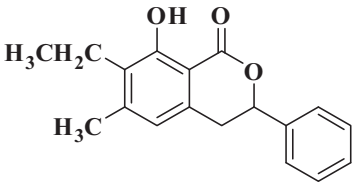
8-Hydroxy-6,7-dimethyl-3-phenylisochroman-1-one (12a):



Starting with ***11a*** (160 mg, 0.50 mmol) and silica gel (Merck silica gel 60, 0.063-0.200 mm, 70-230 mesh, 1.5 g), ***12a*** was obtained as a light yellow solid (65 mg, 48%), m.p = 99-100 ^{o}C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 2.18 (s, 3H, CH_3), 2.25 (s, 3H, CH_3), 3.04 (dd, 1H, J = 16.3, 3.4 Hz, CH_2), 3.24 (dd, 1H, J = 12.2, 4.5 Hz, CH_2), 5.54 (dd, 1H, J = 12.2, 3.4 Hz, CH), 6.56 (s, 1H, H_{Ar}), 7.37-7.43 (m, 5H, H_{Ar}), 11.23 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 11.5, 20.7 (CH_3), 35.0 (CH_2), 80.9 (CH), 104.4 (C_{Ar}), 119.2 (CH_{Ar}), 126.1 ($2CH_{Ar}$), 128.2 (CH_{Ar}), 128.7

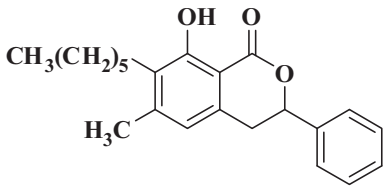
($2CH_{Ar}$), 129.4, 136.7, 142.2, 145.4, 160.3 (C_{Ar}), 168.9 (C=O); IR (KBr): $\tilde{\nu}$ = 2919 (w), 1657 (s), 1573 (m), 1510 (w), 1356 (m), 1272 (m), 1226 (s), 1165 (m), 1097 (s), 1059 (s), 973 (m), 849 (s), 810 (s), 697 (s) cm^{-1}; GC-MS (EI, 70eV): m/z (%): 268 (M^+, 60), 250 (100), 222 (28), 179 (23), 91 (21), 77 (14); elmental analysis: calcd (%) for $C_{17}H_{16}O_3$ (268.31): C = 76.10, H = 6.01; Found: C = 75.81, H = 6.22.

7-Ethyl-8-hydroxy-6-methyl-3-phenylisochroman-1-one (12b):



Starting with 1,3-bis(silyl enol ether), ***4f*** (500 mg, 1.73 mmol), 1-Hydroxy-1-phenyl-5-(trimethylsilyloxy)hex-4-en-3-one, ***10a*** (482 mg, 1.73 mmol) and $TiCl_4$ (0.19 mL, 1.73 mmol), ***12b*** was obtained as a white solid (161 mg, 33%), m.p = 116-117 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.13 (t, 3H, *J* = 7.4 Hz, CH_3), 2.33 (s, 3H, CH_3), 2.70 (q, 2H, *J* = 7.4 Hz, CH_2), 3.02 (dd, 1H, *J* = 16.4, 3.6 Hz, CH_2), 3.23 (dd, 1H, *J* = 12.0, 4.4 Hz, CH_2), 5.53 (dd, 1H, *J* = 12.0, 3.6 Hz, CH), 6.54 (s, 1H, H_{Ar}), 7.36-7.46 (m, 5H, Ph), 11.21 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): 13.1 (CH_3), 19.0 (CH_2), 19.9 (CH_3), 35.0 (CH_2), 80.8 (CH), 105.8 (C_{Ar}), 119.6 (CH_{Ar}), 126.1 ($2CH_{Ar}$), 128.3 (CH_{Ar}), 128.7 ($2CH_{Ar}$), 129.7, 135.6, 138.2, 145.3, 160.1 (C_{Ar}), 170.2 (C=O); IR (KBr): $\tilde{\nu}$ = 3067 (w), 2964 (w), 2873 (w), 1660 (m), 1623 (m), 1571 (w), 1497 (m), 1415 (m), 1349 (m), 1281 (m), 1239 (s), 1162 (s), 1107 (m), 1029 (m), 976 (m), 917 (m), 854 (m), 801 (s), 754 (s), 693 (s) cm^{-1}; GC-MS (EI, 70eV): 282 (M^+, 61), 265 (21), 264 (100), 250 (10), 249 (53), 221 (10), 191 (8), 178 (19), 91 (8), 77 (12); elmental analysis: calcd. (%) for $C_{18}H_{18}O_3$ (282.45): C = 76.57, H = 6.43, Found: C = 76.21, H = 6.21.

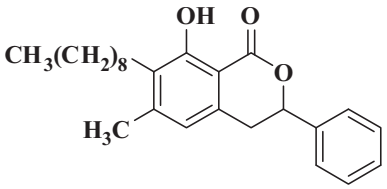
7-Hexyl-8-hydroxy-6-methyl-3-phenylisochroman-1-one (12c):



Starting with 1,3-bis(silyl enol ether), ***4g*** (600 mg, 1.74 mmol), 1-Hydroxy-1-phenyl-5-(trimethylsilyloxy)hex-4-en-3-one, ***10a*** (485 mg, 1.74 mmol) and $TiCl_4$ (0.19 mL, 1.74 mmol), ***12c*** was obtained as a colourless solid (336 mg, 57 %), m.p = 69-71 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 0.70 (t, 3H, *J* = 6.9 Hz, CH_3), 1.08-1.36 (m, 8H, $4CH_2$), 2.15 (s, 3H, CH_3), 2.48 (t, 2H, *J* = 7.1 Hz, CH_2), 2.84 (dd, 1H, *J* = 16.2, 3.4 Hz, CH_2), 3.05 (dd, 1H, *J* = 12.3, 3.9 Hz, CH_2), 5.36 (dd, 1H, *J* = 12.3, 3.4 Hz, CH), 6.36 (s, 1H, CH_{Ar}), 7.18-7.29 (m, 5H, Ph), 11.04 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 15.3, 21.3 (CH_3), 23.8, 27.0, 30.0, 30.7, 32.9, 36.2 (CH_2), 82.0 (CH), 106.9 (C_{Ar}), 120.7 (CH_{Ar}), 127.2 ($2CH_{Ar}$), 129.8 (C_{Ar}), 129.9 ($3CH_{Ar}$), 136.8, 139.4, 146.7, 161.5 (C_{Ar}), 171.4 (C=O); IR (KBr): $\tilde{\nu}$ = 3061 (w), 2921 (m), 2855 (m), 1658 (s),

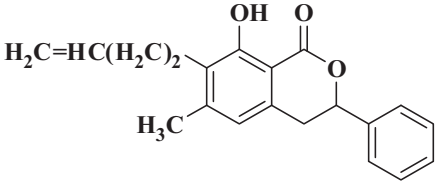
1623 (s), 1573 (w), 1497 (w), 1450 (m), 1353 (m), 1243 (s), 1155 (s), 1085 (m), 1057 (m), 1013 m), 927 (w), 860 (m), 804 (s), 751 (m), 699 (s), 604 (m), 537 (w) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 338 (M^+, 45), 320 (38), 321 (9), 305 (10), 291 (13), 251 (22), 250 (100), 249 (73), 179 (7), 178 (24); HRMS (EI): calcd. for $C_{22}H_{26}O_3$ $[M]^+$: 338.187650; Found: 338.188047.

8-Hydroxy-6-methyl-7-nonyl-3-phenylisochroman-1-one (12d):



Starting with 1,3-bis(silyl enol ether), ***4h*** (600 mg, 1.55 mmol), 1-Hydroxy-1-phenyl-5-(trimethylsilyloxy)hex-4-en-3-one, ***10a*** (430 mg, 1.55 mmol) and $TiCl_4$ (0.17 mL, 1.55 mmol), ***12d*** was obtained as a yellow solid (311 mg, 53 %), m.p = 142-144 °C. ^{1}H-NMR (250 MHz, $CDCl_3$): δ = 0.81 (t, 3H, *J* = 7.3 Hz, CH_3), 1.15-1.48 (m, 14H, $7CH_2$), 2.25 (s, 3H, CH_3), 2.58 (t, 2H, *J* = 7.2 Hz, CH_2), 2.95 (dd, 1H, *J* = 16.3, 3.4 Hz, CH_2), 3.17 (dd, 1H, *J* = 12.3, 4.0 Hz, CH_2), 5.47 (dd, 1H, *J* = 12.3, 3.4 Hz, CH), 6.47 (s, 1H, H_{Ar}), 7.28-7.39 (m, 5H, Ph), 11.14 (s, 1H, OH); ^{13}C-NMR (62 MHz, $CDCl_3$): δ = 14.0 20.1 (CH_3), 22.6, 25.8, 27.2, 28.8, 29.3, 29.5, 29.9, 31.8, 35.0 (CH_2), 80.8 (CH), 105.7 (C_{Ar}), 119.5 (CH_{Ar}), 126.0 ($2CH_{Ar}$), 128.6 (C_{Ar}), 128.6 ($3CH_{Ar}$), 135.5, 138.2, 145.5, 160.3 (C_{Ar}), 170.2 (C=O); IR (KBr): $\tilde{\nu}$ = 2921 (m), 2852 (m), 1659 (m), 1623 (m), 1573 (w), 1502 (w), 1450 (m), 1354 (m), 1269 (m), 1240 (s), 1155 (s), 1086 (m), 1029 (m), 915 (w), 843 (m), 804 (m), 751 (m), 699 (m), 609 (m), 538 (w) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 380 (M^+, 41), 363 (12), 362 (44), 291 (23), 251 (24), 250 (100), 249 (75), 178 (20); HRMS (EI): calcd. for $C_{20}H_{20}O_3$ $[M]^+$: 380.234600; Found: 330.234877.

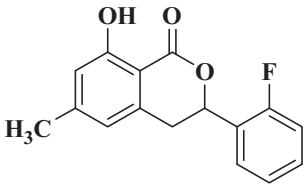
7-(But-3-enyl)-8-hydroxy-6-methyl-3-phenylisochroman-1-one (12e):



Starting with 1,3-bis(silyl enol ether), ***4i*** (600 mg, 1.90 mmol), 1-Hydroxy-1-phenyl-5-(trimethylsilyloxy)hex-4-en-3-one, ***10a*** (528 mg, 1.90 mmol) and $TiCl_4$ (0.20 mL, 1.90 mmol), ***12e*** was obtained as a yellow solid (251 mg, 43 %), m.p = 86-87 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 2.20 (q, 2H, *J* = 8.2 Hz, CH_2), 2.26 (s, 3H, CH_3), 2.69 (t, 2H, *J* = 7.4, CH_{2Ar}), 2.95 (dd, 1H, *J* = 16.4, 3.2 Hz, CH_2), 3.17 (dd, 1H, *J* = 12.0, 4.2 Hz, CH_2), 4.88-5.02 (m, 2H, $=CH_2$), 5.47 (dd, 1H, *J* = 12.0, 3.2 Hz, CH), 5.78-5.90 (m, 1H, =CH), 6.48 (s, 1H, H_{Ar}), 7.26-7.40 (m, 5H, Ph), 11.16 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 20.2 (CH_3), 25.4, 32.8, 35.0 (CH_2), 80.8 (CH), 105.8 (C_{Ar}), 114.7 ($=CH_2$), 119.6 (CH_{Ar}), 126.1 ($2CH_{Ar}$), 127.4 (C_{Ar}), 128.7 ($3CH_{Ar}$), 135.9, 138.2 (C_{Ar}), 138.3 (=CH), 145.6, 160.4 (C_{Ar}), 170.2 (C=O); IR (KBr): $\tilde{\nu}$ = 3062 (w), 2940 (w),1659 (s), 1622 (m), 1573 (m), 1537 (w), 1496 (m), 1415 (m), 1350

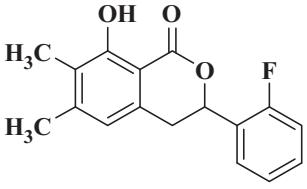
(m), 1287 (m), 1238 (s), 1162 (s), 1058 (m), 1006 (m), 908 (m), 843 (m), 800 (s), 755 (s), 697 (s), 623 (m),586 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 308 (M^+, 19), 268 (6), 267 (28), 250 (19), 249 (100), 178 (13); elmental analysis: calcd (%) for $C_{20}H_{20}O_3$ (308.141): C = 77.90, H = 6.54; Found: C = 77.64, H = 6.86.

3-(2-Fluorophenyl)-8-hydroxy-6-methylisochroman-1-one (12f):



Starting with 1,3-bis(silyl enol ether), ***4c*** (600 mg, 1.78 mmol), 1-(2-fluorophenyl)-1-hydroxy-5-(trimethylsilyloxy)hex-4-en-3-one, ***10b*** (527 mg, 1.78 mmol) and $TiCl_4$ (0.19 mL, 1.78 mmol), ***12f*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a colourless solid (241 mg, 50 %), m.p = 144-146 °C. ^{1}H-NMR (250 MHz, $CDCl_3$): δ = 2.27 (s, 3H, CH_3), 3.03 (dd, 1H, *J* = 16.5, 4.0 Hz, CH_2), 3.16 (dd, 1H, *J* = 16.5, 11.7 Hz, CH_2), 5.79 (dd, 1H, *J* = 11.7, 4.0 Hz, CH), 6.49 (s, 1H, H_{Ar}), 6.67 (s, 1H, H_{Ar}), 6.98-7.06 (m, 1H, H_{Ar}), 7.11-7.17 (m, 1H, H_{Ar}), 7.24-7.33 (m, 1H, H_{Ar}), 7.48-7.55 (m, 1H, H_{Ar}), 10.78 (s, 1H, OH); ^{19}F-NMR (282 MHz, $CDCl_3$): δ = -118.7; ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 21.0 (CH_3), 33.2 ($J_{C,F}$ = 1.5 Hz, CH_2), 73.9 ($J_{C,F}$ = 3.2 Hz, CH), 104.7 (C_{Ar}), 114.6 ($J_{C,F}$ = 21.1 Hz), 115.6, 118.2, 123.5 ($J_{C,F}$ = 3.6 Hz), (CH_{Ar}), 124.5 ($J_{C,F}$ = 12.4 Hz, C_{Ar}), 126.5 ($J_{C,F}$ = 3.2 Hz), 129.2 ($J_{C,F}$ = 8.3 Hz), (CH_{Ar}), 137.8, 147.1, 158.5 ($J_{C,F}$ = 247.5 Hz), 161.2 (C_{Ar}), 168.5 (C=O); IR (KBr): $\tilde{\nu}$ = 3073 (w), 2962 (w), 2909 (w), 1667 (s), 1630 (m), 1575 (m), 1492 (m), 1455 (m), 1366 (m), 1324 (m), 1273 (m), 1230 (s), 1205 (s), 1160 (m), 1088 (m), 1058 (s), 980 (m), 912 (m), 869 (m), 796 (s), 743 (s), 693 (s), 609 (m), 555 (w) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 273 (16), 272 (M^+, 91), 255 (17), 254 (100), 198 (12), 197 (25), 196 (10), 183 (33), 148 (25), 91 (18); HRMS (EI): calcd. for $C_{16}H_{13}FO_3$ $[M]^+$: 272.084320; Found: 272.084445; Anal. calcd. (%) for $C_{16}H_{13}FO_3$ (272.084): C = 70.58, H = 4.81; Found: C = 70.19, H = 4.62.

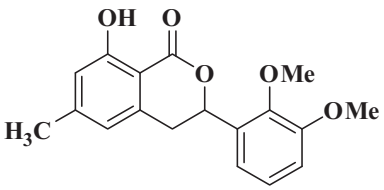
3-(2-Fluorophenyl)-8-hydroxy-6,7-dimethylisochroman-1-one (12g):



Starting with 1,3-bis(silyl enol ether), ***4e*** (600 mg, 2.07 mmol), 1-(2-fluorophenyl)-1-hydroxy-5-(trimethylsilyloxy)hex-4-en-3-one, ***10b*** (613 mg, 2.07 mmol) and $TiCl_4$ (0.22 mL, 2.07 mmol), ***12g*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a light yellowish solid (272 mg, 46 %), m.p = 126-128 °C. ^{1}H-NMR (250 MHz, $CDCl_3$): δ = 2.11 (s, 3H, CH_3), 2.22 (s, 3H, CH_3), 2.99 (dd, 1H, *J* = 16.3, 3.8 Hz, CH_2), 3.13 (dd, 1H, *J* = 16.3, 11.5 Hz, CH_2), 5.77 (dd, 1H, *J* = 11.5, 3.8 Hz, CH), 6.49 (s, 1H, H_{Ar}), 6.97-7.05 (m, 1H, H_{Ar}), 7.11-7.17 (m,

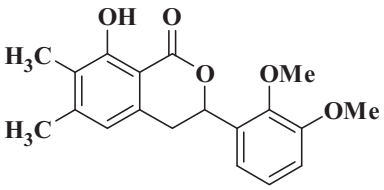
1H, H_{Ar}), 7.23-7.32 (m, 1H, H_{Ar}), 7.49-7.56 (m, 1H, H_{Ar}), 11.11 (s, 1H, OH); ^{19}F-NMR (282 MHz, $CDCl_3$): δ = -118.8; ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 11.1, 20.7 (CH_3), 34.0 ($J_{C,F}$ = 1.0 Hz, CH_2), 75.1 ($J_{C,F}$ = 3.3 Hz, CH), 105.9 (C_{Ar}), 115.5 ($J_{C,F}$ = 21.5 Hz), 119.3 (CH_{Ar}), 123.6 (C_{Ar}), 124.5 ($J_{C,F}$ = 3.5Hz, CH_{Ar}), 125.7 ($J_{C,F}$ = 12.5 Hz, C_{Ar}), 127.5 ($J_{C,F}$ = 3.1 Hz), 130.1 ($J_{C,F}$ = 8.7 Hz), (CH_{Ar}), 135.4, 146.2, 159.5 ($J_{C,F}$ = 247.3 Hz), 160.2 (C_{Ar}), 170.1 (C=O); IR (KBr): $\tilde{\nu}$ = 3049 (w), 2911 (w), 1650 (m), 1615 (m), 1573 (m), 1496 (m), 1451 (m), 1408 (m), 1351 (m), 1266 (m), 1240 (s), 1208 (m), 1152 (s), 1098 (s), 1034 (m), 915 (m), 831 (m), 795 (s), 744 (s), 680 (m), 607 (m), 542 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 286 (M^+, 58), 269 (18), 268 (100), 253 (19), 240 (18), 225 (14), 197 (19), 196 (14 , 177 (7), 162 (9), 91 (10); HRMS (EI): calcd. for $C_{17}H_{15}FO_3$ $[M]^+$: 286.099970; Found: 286.100108; Anal. calcd. (%) for $C_{17}H_{15}FO_3$ (286.100): C = 71.32, H = 5.28; Found: C = 70.89, H = 4.92.

3-(2,3-Dimethoxyphenyl)-8-hydroxy-6-methylisochroman-1-one (12h):



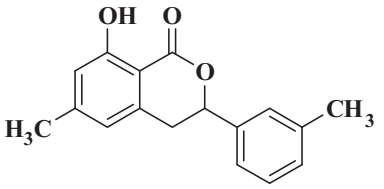
Starting with 1,3-bis(silyl enol ether), ***4c*** (600 mg, 1.78 mmol), 1-(2,3-dimethoxyphenyl)-1-hydroxy-5-(trimethylsilyloxy)hex-4-en-3-one, ***10c*** (602 mg, 1.78 mmol) and $TiCl_4$ (0.19 mL, 1.78 mmol), ***12h*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a yellow solid (212 mg, 38 %), m.p = 142-144 °C. ^{1}H-NMR (250 MHz, $CDCl_3$): δ = 2.26 (s, 3H, CH_3), 2.96 (dd, 1H, *J* = 16.4, 3.4 Hz, CH_2), 3.15 (dd, 1H, *J* = 16.4, 11.9 Hz, CH_2), 3.79 (s, 3H, OCH_3), 3.81 (s, 3H, OCH_3), 5.81 (dd, 1H, *J* = 11.9, 3.4 Hz, CH), 6.47 (s, 1H, H_{Ar}), 6.66 (s, 1H, H_{Ar}), 6.82-6.89 (m, 1H, *J* = 5.8, 3.8 Hz, H_{Ar}), 7.00-7.08 (d, 2H, *J* = 5.8, 3.8 Hz, H_{Ar}), 10.87 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 22.0 (CH_3), 34.5 (CH_2), 55.8, 61.0 (OCH_3), 76.2 (CH), 106.0 (C_{Ar}), 112.6, 116.4, 118.5, 119.1, 124.4 (CH_{Ar}), 131.9, 135.2, 139.5, 146.0, 152.5, 162.2 (C_{Ar}), 170.0 (C=O); IR (KBr): $\tilde{\nu}$ = 2939 (w), 2837 (w), 1714 (s), 1670 (m), 1627 (m), 1579 (m), 1482 (m), 1358 (m), 1313 (m), 1266 (m), 1231 (s), 1145 (s), 1086 (m), 1002 (m), 907 (w), 799 (m), 745 (m), 696 (s), 620 (w), 580 (m) cm^{-1}; EI-MS (EI, 70 eV): *m/z* (%) = 314 (M^+, 100), 296 (61), 281 (12), 268 (13), 253 (32), 225 (16), 165 (5), 148 (15) 91 (8); Anal. calcd. (%) for $C_{18}H_{18}O_5$ (314.11): C = 68.78, H = 5.77; Found: C = 68.51, H = 6.02.

3-(2,3-Dimethoxyphenyl)-8-hydroxy-6,7-dimethylisochroman-1-one (12i):



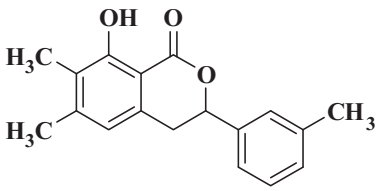
Starting with 1,3-bis(silyl enol ether), ***4e*** (600 mg, 2.07 mmol), 1-(2,3-dimethoxyphenyl)-1-hydroxy-5-(trimethylsilyloxy)hex-4-en-3-one, ***10c*** (700 mg, 2.07 mmol) and $TiCl_4$ (0.22 mL, 2.07 mmol), ***12i*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a yellow solid (237 mg, 35 %), m.p = 141-142 °C. ^{1}H-NMR (250 MHz, $CDCl_3$): δ = 2.11 (s, 3H, CH_3), 2.22 (s, 3H, CH_3), 2.94 (dd, 1H, *J* = 16.4, 3.5 Hz, CH_2), 3.10 (dd, 1H, *J* = 16.3, 12.0 Hz, CH_2), 3.79 (s, 3H, OCH_3), 3.81 (s, 3H, OCH_3), 5.80 (dd, 1H, *J* = 12.0, 3.5 Hz, CH), 6.47 (s, 1H, H_{Ar}), 6.82-6.89 (m, 1H, *J* = 5.8, 3.8 Hz, H_{Ar}), 7.00-7.08 (d, 2H, *J* = 5.8, 3.8 Hz, H_{Ar}), 11.20 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 11.0, 20.7 (CH_3), 34.3 (CH_2), 55.8, 61.0 (OCH_3), 76.3 (CH), 105.6 (C_{Ar}), 112.5, 118.5, 119.3 (CH_{Ar}), 123.4 (C_{Ar}), 124.4 (CH_{Ar}), 132.1, 136.0, 146.0, 152.4, 160.2 (C_{Ar}), 170.5 (C=O); IR (KBr): $\tilde{\nu}$ = 3008 (w), 2923 (w), 2829 (w), 1665 (s), 1627 (m), 1587 (m), 1481 (m), 1416 (m), 1274 (s), 1223 (m), 1158 (m), 1084 (s), 1004 (s), 940 (m), 867 (m), 797 (s), 747 (s), 657 (m), 602 (m), 547 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 328 (M^+, 91), 311 (20), 310 (100), 295 (25), 280 (9), 279 (19), 267 (18), 239 (8), 91 (10); HRMS (EI): calcd. for $C_{19}H_{20}O_5$ $[M]^+$: 328.130530; Found: 328.130831; Anal. calcd. (%) for $C_{19}H_{20}O_5$ (328.131): C = 69.50, H = 6.14; Found: C = 68.51, H = 6.17.

8-Hydroxy-6-methyl-3-m-tolylisochroman-1-one (12j):



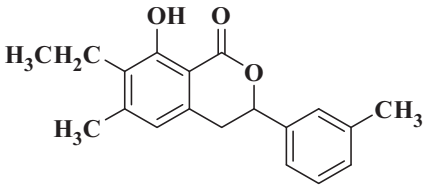
Starting with 1,3-bis(silyl enol ether), ***4a*** (600 mg, 2.30 mmol), 1-hydroxy-1-m-tolyq6l-5-(trimethylsilyloxy)hex-4-en-3-one, ***10d*** (672 mg, 2.30 mmol) and $TiCl_4$ (0.25 mL, 2.30 mmol), ***12j*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a yellow solid (260 mg, 42 %), m.p = 142-144 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 2.26 (s, 3H, CH_3), 2.31 (s, 3H, CH_3), 2.96 (dd, 1H, *J* = 16.7, 3.4 Hz, CH_2), 3.18 (dd, 1H, *J* = 16.7, 12.0 Hz, CH_2), 5.43 (dd, 1H, *J* = 12.0, 3.4 Hz, CH), 6.47 (s, 1H, H_{Ar}), 6.66 (s, 1H, H_{Ar}), 7.09-7.25 (m, 4H, H_{Ar}), 10.84 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 21.4, 22.0 (CH_3), 35.2 (CH_2), 80.8 (CH), 105.9 (C_{Ar}), 116.5, 119.1, 123.1, 126.7, 128.6, 129.5 (CH_{Ar}), 138.0, 138.5, 139.1, 147.9, 162.2 (C_{Ar}), 169.7 (C=O); IR (KBr): $\tilde{\nu}$ = 2921 (w), 1660 (m), 1631 (m), 1582 (s), 1486 (w), 1349 (m), 1274 (m), 1158 (m), 1092 (m), 976 (m), 847 (m), 698 (s) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 268 (M^+, 100), 250 (60), 249 (18), 222 (75), 194 (10), 179 (33), 178 (22), 148 (27), 91 (29); Anal. calcd. (%) for $C_{17}H_{16}O_3$ (268.31): C = 76.10, H = 6.01; Found: C = 75.98, H = 6.32.

8-Hydroxy-6,7-dimethyl-3-m-tolylisochroman-1-one (12k):



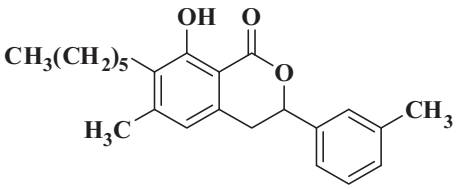
Starting with 1,3-bis(silyl enol ether), ***4e*** (600 mg, 2.07 mmol), 1-hydroxy-1-m-tolyl-5-(trimethylsilyloxy)hex-4-en-3-one, ***10d*** (605 mg, 2.07 mmol) and $TiCl_4$ (0.22 mL, 2.07 mmol), ***12k*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a yellow solid (262 mg, 45 %), m.p = 146-148 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 2.05 (s, 3H, CH_3), 2.17 (s, 3H, CH_3), 2.25 (s, 3H, CH_3), 2.89 (dd, 1H, *J* = 16.3, 3.3 Hz, CH_2), 3.11 (dd, 1H, *J* = 16.3, 12.0 Hz, CH_2), 5.36 (dd, 1H, *J* = 12.0, 3.3 Hz, CH), 6.42 (s, 1H, H_{Ar}), 7.03 (m, 4H, H_{Ar}), 11.12 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 11.0, 20.7, 21.4 (CH_3), 35.0 (CH_2), 80.9 (CH), 105.6 (C_{Ar}), 119.2, 123.1, 126.7, 128.5, 129.4 (CH_{Ar}), 135.6, 138.1, 138.4, 139.9, 146.0, 160.0 (C_{Ar}), 170.2 (C=O); IR (KBr): $\tilde{\nu}$ = 2918 (w), 2859 (w), 1659 (m), 1573 (m), 1445(m), 1349 (m), 1270 (m), 1197 (m), 1097 (m), 1019 (m), 955 (m), 861 (s), 800 (m), 758 (s), 712 (s), 610 (m), 564 (m) cm^{-1}; EI-MS (EI, 70 eV): *m/z* (%) = 282 (M^+, 75), 265 (20), 264 (100), 263 (18), 249 (45), 236 (30), 221 (14), 193 (15), 178 (15), 162 (9), 91 (16); Anal. calcd. (%) for $C_{18}H_{18}O_3$ (282.12): C = 76.57, H = 6.43; Found: C = 76.54, H = 6.44.

7-Ethyl-8-hydroxy-6-methyl-3-m-tolylisochroman-1-one (12l):



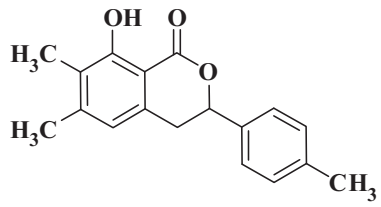
Starting with 1,3-bis(silyl enol ether), ***4f*** (600 mg, 2.07 mmol), 1-hydroxy-1-m-tolyl-5-(trimethylsilyloxy)hex-4-en-3-one, ***10d*** (605 mg, 2.07 mmol) and $TiCl_4$ (0.22 mL, 2.07 mmol), ***12l*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a yellow solid (296 mg, 54 %), m.p = 121-123 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.06 (t, 3H, *J* = 7.5 Hz, CH_3), 2.26 (s, 3H, CH_3), 2.31 (s, 3H, CH_3), 2.63 (q, 2H, *J* = 7.5 Hz, CH_2), 2.93 (dd, 1H, *J* = 16.4, 3.3 Hz, CH_2), 3.15 (dd, 1H, *J* = 16.4, 12.4 Hz, CH_2), 5.42 (dd, 1H, *J* = 12.4, 3.3 Hz, CH), 6.46 (s, 1H, H_{Ar}), 7.09-7.22 (m, 4H, H_{Ar}), 11.14 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 13.1 (CH_3), 19.0 (CH_2), 19.9, 21.4 (CH_3), 35.0 (CH_2), 80.9 (CH), 105.8 (C_{Ar}), 119.5, 123.1, 126.7, 128.5, 129.4 (CH_{Ar}), 129.7, 135.7, 138.2, 138.4, 145.2, 160.2 (C_{Ar}), 170.2 (C=O); IR (KBr): $\tilde{\nu}$ = 2963 (w), 2870 (w), 1660 (s), 1624 (m), 1572 (w), 1504 (w), 1442 (m), 1415 (m), 1349 (m), 1283 (m), 1238 (s), 1160 (s), 1107 (m), 1064 (m), 1033 (m), 977 (m), 912 (m), 858 (w), 805 (m), 755 (s), 706 (s), 611 (m), 573 (s) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 296 (M^+, 60), 279 (21), 278 (100), 264 (11), 263 (56), 235 (9), 192 (9), 191 (9), 91 (8); HRMS (EI): calcd. for $C_{19}H_{20}O_3$ $[M]^+$: 296.140700; Found: 296.141009.

7-Hexyl-8-hydroxy-6-methyl-3-m-tolylisochroman-1-one (12m):



Starting with 1,3-bis(silyl enol ether), ***4g*** (600 mg, 1.74 mmol), 1-hydroxy-1-m-tolyl-5-(trimethylsilyloxy)hex-4-en-3-one, ***10d*** (510 mg, 1.74 mmol) and $TiCl_4$ (0.19 mL, 1.74 mmol), ***12m*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a slight yellow solid (356 mg, 58 %), m.p = 71-73 ^oC. ^1H-NMR (300 MHz, $CDCl_3$): δ = 0.72 (t, 3H, *J* = 6.9 Hz, CH_3), 1.08-1.36 (m, 8H, $4CH_2$), 2.15 (s, 3H, CH_3), 2.21 (s, 3H, CH_3), 2.48 (t, 2H, *J* = 6.2 Hz, CH_2), 2.83 (dd, 1H, *J* = 16.2, 3.2 Hz, CH_2), 3.05 (dd, 1H, *J* = 16.2, 12.4 Hz, CH_2), 5.33 (dd, 1H, *J* = 12.4, 3.2 Hz, CH), 6.36 (s, 1H, H_{Ar}), 6.99-7.16 (m, 4H, H_{Ar}), 11.04 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 13.5, 21.3, 22.6 (CH_3), 23.8, 27.0, 30.0, 30.8, 32.9, 36.3 (CH_2), 82.1 (CH), 106.9 (C_{Ar}), 120.7, 124.2, 127.9, 129.6 (CH_{Ar}), 129.7 (C_{Ar}), 130.6 (CH_{Ar}), 136.9, 139.4, 139.6, 146.6, 161.5 (C_{Ar}), 171.5 (C=O); IR (KBr): $\tilde{\nu}$ = 2922 (m), 2855 (w), 1661 (s), 1622 (m), 1573 (w), 1512 (w), 1435 (m), 1354 (m), 1292 (m), 1244 (s), 1162 (s), 1078 (m), 1013 (m), 972 (w), 909 (w), 842 (m), 788 (s), 700 (m), 605 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 352 (M^+, 59), 335 (10), 334 (57), 319 (12), 265 (26), 264 (100), 263 (74), 249 (17), 192 (14), 191 (13); HRMS (EI): calcd. for $C_{23}H_{28}O_3$ $[M]^+$: 352.203300; Found: 352.203683.

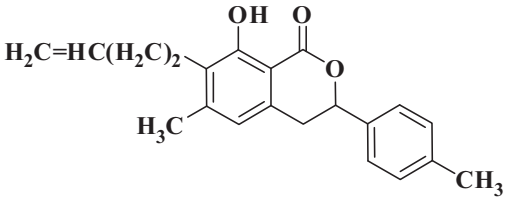
8-Hydroxy-6,7-dimethyl-3-p-tolylisochroman-1-one (12n):



Starting with 1,3-bis(silyl enol ether), ***4d*** (600 mg, 2.18 mmol), 1-Hydroxy-1-p-tolyl-5-(trimethylsilyloxy)hex-4-en-3-one, ***10e*** (640 mg, 2.18 mmol) and $TiCl_4$ (0.24 mL, 2.18 mmol), ***12n*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as an orange solid (265 mg, 43 %), m.p = 107-109 ^oC. ^1H-NMR (300 MHz, $CDCl_3$): δ = 2.16 (s, 3H, CH_3), 2.28 (s, 3H, CH_3), 2.36 (s, 3H, CH_3), 2.99 (dd, 1H, *J* = 16.1, 3.2 Hz, CH_2), 3.21 (dd, 1H, *J* = 16.1, 12.1 Hz, CH_2), 5.49 (dd, 1H, *J* = 12.1, 3.2 Hz, CH), 6.54 (s, 1H, H_{Ar}), 7.20 (d, 2H, *J* = 7.9 Hz, H_{Ar}), 7.32 (d, 2H, *J* = 7.9 Hz, H_{Ar}), 11.26 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 11.0, 20.7, 21.1 (CH_3), 34.8 (CH_2), 80.8 (CH), 105.6 (C_{Ar}), 119.2 (CH_{Ar}), 123.4 (C_{Ar}), 126.1 ($2CH_{Ar}$), 129.3 ($2CH_{Ar}$), 135.2, 135.6, 138.6, 146.0, 160.1 (C_{Ar}), 170.3 (C=O); IR (KBr): $\tilde{\nu}$ = 2920 (w), 1662 (s), 1575 (w), 1517 (m), 1449 (m), 1367 (m), 1276 (s), 1254 (s), 1160 (s), 1098 (m), 1017 (m), 965 (w), 859 (m), 809 (s), 750 (s), 695 (m) cm^{-1}; GC-MS (EI, 70eV): *m/z* (%) = 282 (M^+, 65), 264 (100), 249 (34), 236 (24), 221 (15), 193

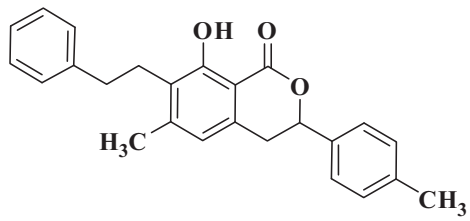
(16), 178 (20), 165 (8), 91 (21), 77 (9); HRMS (EI): calcd. for $C_{18}H_{18}O_3$ $[M]^+$: 282.125050; Found: 282.125624.

7-(But-3-enyl)-8-hydroxy-6-methyl-3-p-tolylisochroman-1-one (12o):



Starting with 1,3-bis(silyl enol ether), ***4i*** (600 mg, 1.90 mmol), 1-hydroxy-1-p-tolyl-5-(trimethylsilyloxy)hex-4-en-3-one, ***10e*** (555 mg, 1.90 mmol) and $TiCl_4$ (0.20 mL, 1.90 mmol), ***12o*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a light orange solid (234 mg, 38 %), m.p = 98-99 ^oC. ^1H-NMR (300 MHz, $CDCl_3$): δ = 2.31 (s, 3H, CH_3), 2.35 (s, 3H, CH_3), 2.75 (t, 2H, J = 7.7 Hz, CH_2), 2.96 (dd, 1H, J = 16.6, 3.3 Hz, CH_2), 3.19 (dd, 1H, J = 16.6, 12.2 Hz, CH_2), 4.95-5.07 (m, 2H, CH_2), 5.46 (dd, 1H, J = 12.2, 3.3 Hz, CH_2), 5.85-5.96 (m, 1H, =CH), 6.53 (s, 1H, H_{Ar}), 7.20 (d, 2H, J = 8.0 Hz, H_{Ar}), 7.31 (d, 2H, J = 8.0 Hz, H_{Ar}), 11.25 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 20.3, 21.2 (CH_3), 26.0, 32.8, 35.0 (CH_2), 80.9 (CH-O), 105.9 (C_{Ar}), 114.6 (=CH_2), 119.6 (CH_{Ar}), 126.5 ($2CH_{Ar}$), 127.4 (C_{Ar}), 129.4 ($2CH_{Ar}$), 135.3, 136.1 (C_{Ar}), 138.4 (=CH), 138.6, 145.6, 160.4 (C_{Ar}), 170.3 (C=O); IR (KBr): $\tilde{\nu}$ = 3079 (w), 2953 (w), 1656 (s), 1573 (w), 1514 (m), 1444 (m), 1350 (m), 1241 (s), 1158 (s), 1072 (m), 1017 (m), 906 (m), 815 (s), 745 (s), 652 (w), 599 (m), 526 (m) cm^{-1}; GC-MS (EI, 70eV): m/z (%) = 322 (M^+, 19), 304 (3), 281 (15), 264 (19), 263 (100), 192 (9), 191 (7), 91 (4), 77 (2); HRMS (EI): calcd. for $C_{21}H_{22}O_3$ $[M^+]$: 322.156350; Found: 322.156016.

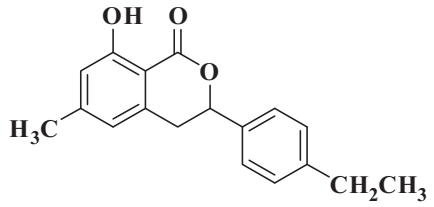
8-Hydroxy-6-methyl-7-phenethyl-3-p-tolylisochroman-1-one (12p):



Starting with 1,3-bis(silyl enol ether), ***4j*** (600 mg, 1.64 mmol), 1-hydroxy-1-p-tolyl-5-(trimethylsilyloxy)hex-4-en-3-one, ***10e*** (480 mg, 1.64 mmol) and $TiCl_4$ (0.18 mL, 1.64 mmol), ***12p*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a colourless solid (245 mg, 40 %), m.p = 151-152 ^oC. ^1H-NMR (300MHz, $CDCl_3$): δ = 2.19 (s, 3H, CH_3), 2.36 (s, 3H, CH_3), 2.81 (t, 2H, J = 4.5 Hz, CH_2), 2.93 (t, 2H, J = 4.5 Hz, CH_2), 2.99 (dd, 1H, J = 16.6, 3.2 Hz, CH_2), 3.22 (dd, IH, J = 16.6, 12.2 Hz, CH_2), 5.49 (dd, 1H, J = 12.2, 3.2 Hz CH), 6.51 (s, 1H, H_{Ar}), 7.19-7.34 (m, 9H, H_{Ar}), 11.30 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 20.1, 21.2 (CH_3), 28.4, 34.9, 35.0 (CH_2), 80.8 (CH), 105.9 (C_{Ar}), 119.6, 125.9 (CH_{Ar}), 126.1

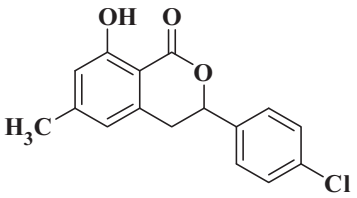
(2CH_{Ar}), 127.3 (C_{Ar}), 128.3 (2CH_{Ar}), 128.5 (2CH_{Ar}), 129.4 (2CH_{Ar}), 135.3, 136.2, 138.7, 142.2, 145.7, 160.4 (C_{Ar}), 170.3 (C=O); IR (KBr): $\tilde{\nu}$ = 3027 (w), 2953 (w), 1663 (s), 1573 (w), 1516 (m), 1449 (m), 1361 (m), 1288 (s), 1247 (s), 1160 (s), 1081 (m), 1016 (m), 968 (w), 918 (w), 858 (m), 751 (s), 694 (s) cm^{-1}; GC-MS (EI, 70eV): m/z (%) = 372 (M^+, 20), 281 (20), 264 (19), 263 (100), 192 (9),191 (7), 91 (11), 77 (3); Anal. calcd. (%) for $C_{25}H_{26}O_3$ (372.17): C = 80.80, H = 6.78; Found: C = 80.72, H = 6.53.

3-(4-Ethylphenyl)-8-hydroxy-6-methylisochroman-1-one (12q):



Starting with 1,3-bis(silyl enol ether), ***4b*** (600 mg, 2.18 mmol), 1-(4-ethylphenyl)-1-hydroxy-5-(trimethylsilyloxy) hex-4-en-3-one, ***10f*** (668 mg, 2.18 mmol) and $TiCl_4$ (0.24 mL, 2.18 mmol), ***12q*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a yellow solid (295 mg, 48 %), m.p = 103-104 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.24 (t, 3H, *J* = 7.6 Hz, CH_3), 2.34 (s, 3H, CH_3), 2.67 (q, 2H, *J* = 7.6 Hz, CH_2), 3.04 (dd, 1H, *J* = 16.6, 3.2 Hz, CH_2), 3.21 (dd, 1H, *J* = 16.6, 12.1 Hz, CH_2), 5.51 (dd, 1H, *J* = 12.1, 3.2 Hz, CH), 6.55 (s, 1H, H_{Ar}), 6.73 (s, 1H, H_{Ar}), 7.21 (d, 2H, *J* = 8.1 Hz, H_{Ar}), 7.36 (d, 2H, *J* = 8.1 Hz, H_{Ar}), 10.93 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 15.5, 22.1 (CH_3), 28.6, 35.1 (CH_2), 80.7 (CH), 106.0 (C_{Ar}), 116.5, 119.1 (CH_{Ar}), 126.2 (2CH_{Ar}), 128.2 (2CH_{Ar}), 135.3, 139.1, 145.1, 147.9, 162.2 (C_{Ar}), 169.8 (C=O); IR (KBr): $\tilde{\nu}$ = 2966 (w), 1660 (s), 1576 (m), 1497 (w), 1347 (m), 1279 (m), 1201 (s), 1058 (s), 1008 (w), 913 (w), 829 (s), 769 (w), 700 (s) cm^{-1}; GC-MS (EI, 70eV): m/z (%) = 282 (M^+, 100), 265 (15), 264 (92), 236 (28), 221 (62), 178 (11) 148 (17), 91 (10), 77 (4); Anal. calcd. (%) for $C_{18}H_{18}O_3$ (282.45): C = 76.57, H = 6.43; Found: C = 76.46, H = 6.12.

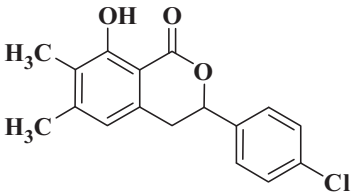
3-(4-Chlorophenyl)-8-hydroxy-6-methylisochroman-1-one (12r):



Starting with 1,3-bis(silyl enol ether), ***4a*** (600 mg, 2.30 mmol), 1-(4-chlorophenyl)-1-hydroxy-5-(trimethylsilyloxy)hex-4-en-3-one, ***10g*** (720 mg, 2.30 mmol) and $TiCl_4$ (0.25 ml, 2.30 mmol), ***12r*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a colourless solid (365 mg, 55 %), m.p = 115-116 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 2.34 (s, 3H, CH_3), 3.04 (dd, 1H, *J* = 16.4, 3.6 Hz, CH_2), 3.21 (dd, 1H, *J* = 16.4, 11.8 Hz, CH_2), 5.53 (dd, 1H, *J* = 11.8, 3.6 Hz, CH), 6.56 (s, 1H, H_{Ar}), 6.74 (s, 1H, H_{Ar}), 7.38-7.40 (m, 4H, H_{Ar}), 10.85

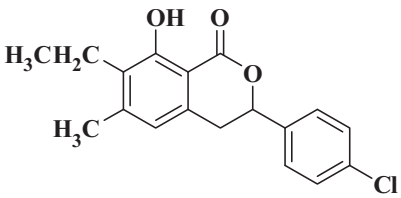
(s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 22.0 (CH_3), 35.1 (CH_2), 79.8 (CH), 105.8 (C_{Ar}), 116.7, 119.1 (CH_{Ar}), 127.4 ($2CH_{Ar}$), 128.9 ($2CH_{Ar}$), 134.6, 136.6, 138.6, 148.2, 162.2 (C_{Ar}), 169.4 (C=O); IR (KBr): $\tilde{\nu}$ = 3070 (w), 2959 (w), 1673 (s), 1577 (m), 1491 (m), 1409 (m), 1360 (m), 1276 (m), 1229 (s), 1160 (m), 1085 (s), 1010 (m), 968 (w), 914 (m), 839 (s), 797 (s), 730 (s), 692 (s) cm^{-1}; GC-MS (EI, 70eV): m/z (%) = 288 (M^+, ^{35}Cl, 87), 270 (100), 242 (45), 207 (21), 179 (39), 148 (26), 91 (12); HRMS (EI): calcd. for $C_{16}H_{13}ClO_3$ ($[M]^+$, ^{35}Cl): 288.064420; Found: 288.064851.

3-(4-Chlorophenyl)-8-hydroxy-6,7-dimethylisochroman-1-one (12s):



Starting with 1,3-bis(silyl enol ether), ***4d*** (500 mg, 1.82 mmol), 1-(4-chlorophenyl)-1-hydroxy-5-(trimethylsilyloxy)hex-4-en-3-one, ***10g*** (570 mg, 1.82 mmol) and $TiCl_4$ (0.20 ml, 1.82 mmol), ***12s*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a white solid (275 mg, 50 %), m.p = 125-126 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 2.17 (s, 3H, CH_3), 2.29 (s, 3H, CH_3), 3.04 (dd, 1H, *J* = 16.3, 3.5 Hz, CH_2), 3.18 (dd, 1H, *J* = 16.3, 11.8 Hz, CH_2), 5.51 (dd, 1H, *J* = 11.8, 3.5 Hz, CH), 6.55 (s, 1H, H_{Ar}), 7.37-7.39 (m, 4H, H_{Ar}), 11.18 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 11.1, 20.7 (CH_3), 34.9 (CH_2), 80.0 (CH), 105.4 (C_{Ar}), 119.3 (CH_{Ar}), 123.7 (C_{Ar}), 127.4 ($2CH_{Ar}$), 128.9 ($2CH_{Ar}$), 134.5, 135.1, 136.7, 146.2, 160.2 (C_{Ar}), 169.9 (C=O); IR (KBr): $\tilde{\nu}$ = 3152 (w), 2920 (w), 1651 (s), 1623 (m), 1574 (w), 1491 (m), 1354 (m), 1273 (m), 1215 (m), 1160 (s), 1074 (s), 964 (m), 872 (m), 815 (s), 718 (m) cm^{-1}; GC-MS (EI, 70eV): m/z (%) = 302 (M^+, ^{35}Cl, 52), 284 (100), 269 (17), 256 (15), 249 (26), 241 (11), 193 (12), 178 (24), 165 (8), 91 (13), 77 (12); HRMS (EI): calcd. for $C_{17}H_{15}ClO_3$ ($[M]^+$, ^{35}Cl): 302.070420; Found: 302.070344.

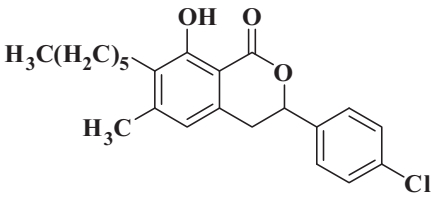
3-(4-Chlorophenyl)-7-ethyl-8-hydroxy-6-methylisochroman-1-one (12t):



Starting with 1,3-bis(silyl enol ether), ***4f*** (600 mg, 2.07 mmol), 1-(4-chlorophenyl)-1-hydroxy-5-(trimethylsilyloxy)hex-4-en-3-one, ***10g*** (648 mg, 2.07 mmol) and $TiCl_4$ (0.22 mL, 2.07 mmol), ***12t*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a brownish solid (347 mg, 53 %), m.p = 110-112 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.06 (t, 3H, *J* = 7.4 Hz, CH_3), 2.26 (s, 3H, CH_3), 2.63 (q, 2H, *J* = 7.4 Hz, CH_2), 2.94 (dd, 1H, *J* = 16.4, 3.2 Hz, CH_2), 3.11 (dd, 1H, *J* = 16.4, 12.0 Hz, CH_2), 5.44 (dd, 1H, *J* = 12.0,

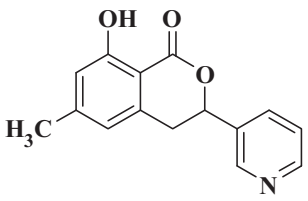
3.2 Hz, CH), 6.47 (s, 1H, H_{Ar}), 7.31-7.33 (m, 4H, H_{Ar}), 11.07 (s, 1H, OH). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 12.0 (CH_3), 18.0 (CH_2), 18.9 (CH_3), 33.9 (CH_2), 79.0 (CH), 104.6 (C_{Ar}), 118.6 (CH_{Ar}), 126.4 ($2CH_{Ar}$), 127.9 ($2CH_{Ar}$), 128.9, 133.5, 134.2, 135.7, 144.4, 159.2 (C_{Ar}), 168.9 (C=O); IR (KBr): $\tilde{\nu}$ = 2930 (m), 2871 (w), 1658 (s), 1620 (m), 1493 (m), 1417 (m), 1359 (m), 1274 (m), 1236 (s), 1151 (s), 1062 (m), 1012 (m), 917 (m), 802 (s), 747 (s), 682 (m), 606 (s) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 316 (M^+, ^{35}Cl, 49), 300 (34), 299 (22), 298 (100), 285 (14), 283 (44), 191 (11), 91 (11); HRMS (EI): calcd. for $C_{18}H_{17}ClO_3$ ($[M]^+$, ^{35}Cl): 316.086070; Found: 316.086347.

3-(4-Chlorophenyl)-7-hexyl-8-hydroxy-6-methylisochroman-1-one (12u):



Starting with 1,3-bis(silyl enol ether), ***4g*** (600 mg, 1.74 mmol), 1-(4-chlorophenyl)-1-hydroxy-5-(trimethylsilyloxy) hex-4-en-3-one, ***10g*** (545 mg, 1.74 mmol) and $TiCl_4$ (0.19 mL, 1.74 mmol), ***12u*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a viscous orange oil (357 mg, 55 %). ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 0.72 (t, 3H, *J* = 6.9 Hz, CH_3), 1.08-1.35 (m, 8H, $4CH_2$), 2.15 (s, 3H, CH_3), 2.48 (t, 2H, *J* = 7.1 Hz, CH_2), 2.84 (dd, 1H, *J* = 16.2, 3.4, CH_2), 3.01 (dd, 1H, *J* = 16.2, 12.0 Hz, CH_2), 5.34 (dd, 1H, *J* = 12.0, 3.4 Hz, CH), 6.36 (s, 1H, H_{Ar}), 7.20-7.22 (m, 4H, H_{Ar}), 10.97 (s, 1H, OH); ^{13}C-NMR (62 MHz, $CDCl_3$): δ = 15.2, 21.3 (CH_3), 23.8, 27.0, 29.9, 30.7, 32.9, 36.2 (CH_2), 81.2 (CH), 106.8 (C_{Ar}), 120.7 (CH_{Ar}), 128.6 ($2CH_{Ar}$), 129.9 (C_{Ar}), 130.1 ($2CH_{Ar}$), 135.7, 136.4, 138.0, 146.9, 161.6 (C_{Ar}), 171.1 (C=O); IR (neat): $\tilde{\nu}$ = 3197 (w), 2924 (m), 2853 (m), 1934 (w), 1747 (w), 1662 (s), 1620 (m), 1573 (w), 1492 (m), 1434 (m), 1346 (m), 1272 (m), 1156 (s), 1073 (m), 1010 (s), 874 (w), 818 (s), 747 (m), 639 (m), 539 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 372 (M^+, ^{35}Cl, 43), 356 (14), 354 (41), 339 (12), 325 (11), 286 (35), 285 (42), 284 (100), 283 (63), 249 (8), 192 (13), 191 (15), 177 (8); HRMS (EI): calcd. for $C_{22}H_{25}ClO_3$ ($[M]^+$, ^{35}Cl): 372.895230; Found: 372.638279.

8-Hydroxy-6-methyl-3-(pyridin-3-yl)isochroman-1-one (12w):



Starting with 1,3-bis(silyl enol ether), ***4a*** (600 mg, 2.30 mmol), 1-hydroxy-1-(pyridin-3-yl)-5-(trimethylsilyloxy)hex-4-en-3-one, ***10h*** (643 mg, 2.30 mmol) and $TiCl_4$ (0.25 ml, 2.30 mmol), ***12w*** was isolated after column chromatography (silica gel, n-heptane/EtOAc = 23:2) as a slight yellow solid (216 mg, 37 %), m.p = 124-126 °C. ^{1}H-NMR (250 MHz, $CDCl_3$): δ = 2.28 (s, 3H, CH_3), 3.02 (dd, 1H, *J* = 16.6, 3.8 Hz, CH_2), 3.20 (dd, 1H, *J* = 16.6, 12.2 Hz, CH_2), 5.54 (dd, 1H, *J*

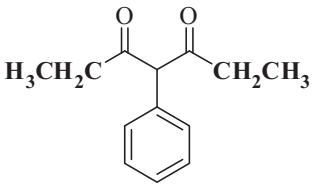
= 12.2, 3.8 Hz, CH), 6.51 (s, 1H, H_{Ar}), 6.68 (s, 1H, H_{Ar}), 7.30 (dd (br.), 1H, *J* = 7.9, 4.9 Hz, H_{Pyrid}), 7.77 (dt (br.), 1H, *J* = 7.9, 1.9 Hz, H_{Pyrid}), 8.56 (dd (br.), 1H, *J* = 4.9, 1.6 Hz, H_{Pyrid}), 8.61 (d (br.), 1H, *J* = 1.6 Hz, H_{Pyrid}), 10.73 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 22.0 (CH_3), 34.8 (CH_2), 78.3 (CH), 105.7 (C_{Ar}), 116.8, 119.2 (CH_{Ar}), 123.7 (CH_{Pyrid}), 133.8 (C_{Ar}), 133.9 (CH_{Pyrid}), 138.3 (C_{Pyrid}), 147.6 (CH_{Pyrid}), 148.3 (C_{Ar}), 150.1 (CH_{Pyrid}), 162.3 (C_{Ar}), 169.2 (C=O); IR (KBr): $\tilde{\nu}$ = 3145 (br. w), 2919 (w), 1659 (s), 1578 (m), 1495 (m), 1417 (m), 1349 (m), 1269 (s), 1202 (s), 1157 (m), 1096 (m), 975 (m), 886 (m), 814 (s), 781 (m), 695 (s) cm^{-1}; GC-MS (EI, 70eV): m/z (%) = 255 (M^+, 100), 210 (93), 180 (73), 148 (52), 91 (17), 77 (6); Anal. calcd. (%) for $C_{15}H_{13}NO_3$ (255.09): C = 70.58, H = 5.13, N = 5.49; Found: C = 69.53, H = 5.32, N = 5.02.

7.3 Synthesis of Sterically Encumbered Biaryls based on a Copper(I)-Catalyzed Arylation / [3+3] Cyclocondensation′ Strategy.

Typical procedure for the synthesis of 3-substituted alkane-2,4-diones (15a-c):

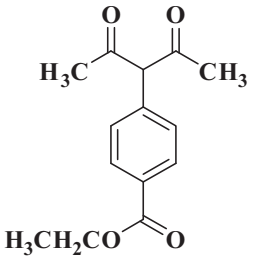
A mixture of ***13a-b*** (1.5 mmol), ***14a-c*** (0.5 mmol), **K_2CO_3** (2.0 mmol), **CuI** (0.05 mmol), **L-proline** (1.0 mmol) in a 2 mL of **DMSO** was heated at 90-120 °C under Argon atmosphere for 6-12 h. The cooled solution was poured into 1.0 N HCl, extracted with EtOAc. The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated in vacuo. The residue was chromatographed to afford **3a-f**.

4-Phenylheptane-3,5-dione (15a):



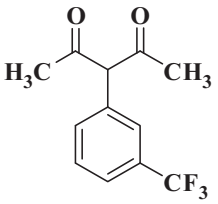
Starting with ***13a*** (1.25 mL, 11.25 mmol), ***14a*** (4.58 mL, 23.81 mmol), **K_2CO_3** (6.23 g, 45.08 mmol), **CuI** (0.257 g, 12 mol%), **L-proline** (0.324 g, 25 mol%) in 45.0 mL of **DMSO** heating for 8 h at 100 °C, ***15a*** was obtained as a slight brownish oil (1.70 g, 74%). ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.01 (t, 6H, *J* = 7.3 Hz, CH_3), 2.11 (q, 4H, *J* = 7.3 Hz, CH_2), 7.16-7.32 (m, 5H, H_{Ar}), [enol form much more stable than keto form and because of rapid exchange of proton between two oxygen atoms (in $CDCl_3$), this proton is almost invisible in ^{1}H-NMR]; ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 9.6 (CH_3), 29.9 (CH_2), 113.9 (=C, enol form), 127.4 (CH_{Ar}), 128.8 ($2CH_{Ar}$), 129.3 ($2CH_{Ar}$), 136.5 (C_{Ar}), 194.1 (C=O).

Ethyl 4-(2,4-dioxopentan-3-yl)benzoate (15b):



Starting with ***13b*** (3.9 mL, 38.0 mmol), ***14b*** (2.1 mL, 12.6 mmol), **K_2CO_3** (7.0 g, 50.5 mmol), **CuI** (0.24 g, 10 mol%), **L-proline** (0.29 g, 20 mol%) in 50 mL of **DMSO** heating for 12 h at 120 °C, ***15b*** was obtained as a white solid (2.26 g, 72%). ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.41 (t, 3H, *J* = 7.1 Hz, CH_3), 1.89 (s, 6H, CH_3), 4.38 (q, 2H, *J* = 7.1 Hz, OCH_2), 7.26 (d, 2H, *J* = 8.4 Hz, H_{Ar}), 8.12 (d, 2H, *J* = 8.4 Hz, H_{Ar}), [enol form much more stable than keto form and because of rapid exchange of proton between two oxygen atoms (in $CDCl_3$), this proton is almost invisible in ^{1}H-NMR]; ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 14.3, 24.1 (CH_3), 61.1 (OCH_2), 114.5 (=C, enol form), 129.8 (C_{Ar}), 130.0 ($2CH_{Ar}$), 131.2 ($2CH_{Ar}$), 141.7 (C_{Ar}), 166.2, 190.6 (C=O).

3-(3-(Trifluoromethyl)phenyl)pentane-2,4-dione (15c):



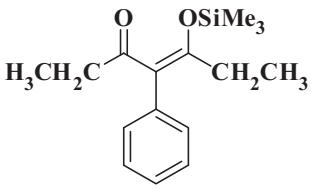
Starting with ***13b*** (7.7 mL, 75.0 mmol), ***14c*** (3.6 mL, 25.0 mmol), **K_2CO_3** (13.8 g, 100.0 mmol), **CuI** (0.47 g, 10 mol%), **L-proline** (0.57 g, 20 mol%) in 100 mL of **DMSO** heating for 10 h at 90 °C, ***15c*** was obtained as a brown viscous oil (3.96 g, 65%). ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.93 (s, 6H, CH_3), 7.20 (d (br.), 1H, *J* = 6.7 Hz, H_{Ar}), 7.28 (s (br.), 1H, H_{Ar}), 7.44 (t (br.), 1H, *J* = 6.7, 7.2 Hz, H_{Ar}), 7.55 (d (br.), 1H, *J* = 7.2 Hz, H_{Ar}), [enol form much more stable than keto form and because of rapid exchange of proton between two oxygen atoms (in $CDCl_3$), this proton is almost invisible in ^{1}H-NMR]; ^{19}F-NMR (282 MHz, $CDCl_3$): δ = -62.5; ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 23.1 (CH_3), 114.5 (=C, enol form), 123.0 ($J_{C,F}$ = 271 Hz, C_{CF3}), 123.4 ($J_{C,F}$ = 3.6 Hz, CH_{Ar}), 126.8 ($J_{C,F}$ = 3.8 Hz), 128.4 (CH_{Ar}), 130.3 ($J_{C,F}$ = 31.7 Hz, C_{Ar}), 133.5 ($J_{C,F}$ = 1.6 Hz, CH_{Ar}), 135.5 (C_{Ar}), 190.4 (C=O).

General procedure for the synthesis of Silyl enol ethers (16a-c):

To a stirred benzene solution (2.5 mL per 1.0 mmol of 3a-f) of ***15a-c*** (1.0 equiv.) was added triethylamine (1.6 equiv.). After stirring the solution for 2 h, trimethylchlorosilane (1.8 equiv.) was added. The solution was stirred for 72 h and, subsequently, the solvent was removed in vacuo and hexane (1.5 mL per 1.0 mmol of starting material) was added to the residue to give a suspension. The latter was filtered under argon atmosphere. The filtrate was concentrated in vacuo to give silyl enol ethers ***16a-c***, which were used without further purification. Due to the unstable nature of the

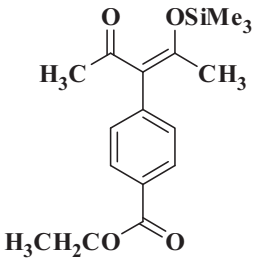
products, MS and analytical data could not be obtained. All products were obtained as mixtures of E/Z-isomers.

4-Phenyl-5-(trimethylsilyloxy)hept-4-en-3-one (16a):



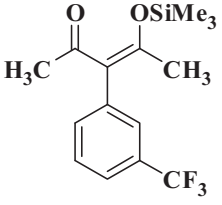
Starting with **benzene** (18 mL), ***15a*** (1.46 g, 7.15 mmol), **triethylamine** (1.36 mL, 11.44 mmol) and **trimethylchlorosilane** (1.92 mL, 12.88 mmol), ***16b*** was isolated as a brownish oil (1.78 g, 90%). ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 0.18 (s, 9H, Si[CH_3]$_3$), 1.06 (t, 3H, *J* = 7.4 Hz, CH_3), 1.11 (t, 3H, *J* = 7.3 Hz, CH_3), 2.14 (q, 2H, *J* = 7.4 Hz, CH_2), 2.56 (q, 2H, *J* = 7.3 Hz, CH_2), 7.16-7.32 (m, 5H, H_{Ar}); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 0.3 (Si[CH_3]$_3$), 9.6, 9.8 (CH_3), 29.2, 30.2 (CH_2), 113.3 (=C), 127.5 (CH_{Ph}), 128.8 ($2CH_{Ph}$), 129.4 ($2CH_{Ph}$), 136.6 (C_{Ar}), 186.8 (COSi), 193.8 (C=O).

Ethyl 4-(4-oxo-2-(trimethylsilyloxy)pent-2-en-3-yl)benzoate (16b):



Starting with **benzene** (21.1 mL), ***15b*** (2.1 g, 8.45 mmol), **triethylamine** (1.6 mL, 13.5 mmol) and **trimethylchlorosilane** (2.2 mL, 15.21 mmol), ***16b*** was isolated as a colorless oil (2.16 g, 80%). ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 0.21 (s, 9H, Si[CH_3]$_3$), 1.40 (t, 3H, *J* = 7.1 Hz, CH_3), 1.88 (s, 3H, CH_3), 1.93 (s, 3H, CH_3), 4.36 (q, 2H, *J* = 7.1 Hz, OCH_2), 7.26 (d, 2H, *J* = 8.4 Hz, H_{Ar}), 8.12 (d, 2H, *J* = 8.4 Hz, H_{Ar}); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 0.4 (Si[CH_3]$_3$), 14.3, 23.8, 24.2 (CH_3), 61.1 (OCH_2), 114.7 (=C), 129.8 (C_{Ar}), 130.0 ($2CH_{Ar}$), 131.2 ($2CH_{Ar}$), 141.8 (C_{Ar}), 166.3 (C=O), 185.9 (COSi), 190.5 (C=O).

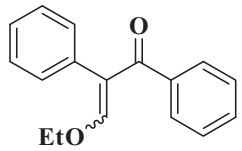
3-(3-(Trifluoromethyl)phenyl)-4-(trimethylsilyloxy)pent-3-en-2-one (16c):



Starting with **benzene** (32.5 mL), ***15c*** (3.2 g, 13.1 mmol), **triethylamine** (2.4 mL, 20.9 mmol) and **trimethylchlorosilane** (3.5 mL, 23.5 mmol), ***16c*** was isolated as a slight dark brown oil (3.5 g, 86%). ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 0.21 (s, 9H, Si[CH_3]$_3$), 1.93 (s, 3H, CH_3), 1.97 (s, 3H, CH_3), 7.21 (d (br.), 1H, *J* = 6.7 Hz, H_{Ar}), 7.29 (s (br.), 1H, H_{Ar}), 7.45 (t (br.), 1H, *J* = 6.7, 7.2 Hz, H_{Ar}), 7.54 (d (br.), 1H, *J* = 7.2 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, $CDCl_3$): δ = -62.5; ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 0.4 (Si[CH_3]$_3$), 21.4, 23.6 (CH_3), 114.3 (=C), 122.9 ($J_{C,F}$ = 270 Hz, CF_3), 123.4 ($J_{C,F}$ =

3.6 Hz, CH_{Ar}), 126.8 ($J_{C,F}$ = 3.8 Hz), 128.5 (CH_{Ar}), 130.4 ($J_{C,F}$ = 31.8 Hz, C_{Ar}), 133.6 ($J_{C,F}$ = 1.6 Hz, CH_{Ar}), 135.3 (C_{Ar}), 186.5 (COSi), 191.1 (C=O).

Synthesis of 3-ethoxy-1,2-diphenylprop-2-en-1-one (19):

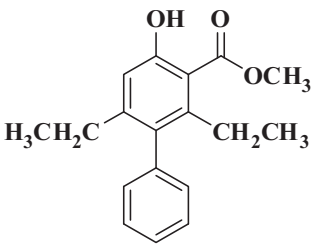


Deoxybenzoin (2.0 g, 10.2 mmol) was added to a mixture of **triethyl orthoformate** (2.5 mL) and **acetic anhydride** (2.5 mL) and the mixture was heated under reflux for 8 h. The mixture was concentrated in vacuo and purified by chromatography (silica gel, n-heptane/EtOAc) to give ***19*** as a pale green oil (1.28 g, 50%, 92:8 mixture of geometric isomers, only NMR data of the major isomer are listed). ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.23 (t, *J* = 7.1 Hz, 3H, CH_3), 3.97 (q, *J* = 7.2 Hz, 2H, CH_2), 7.13-7.32 (m, 10H, CH_{Ar}), 7.54-7.55 (br. s, 1H, CH); ^{13}C-NMR ($CDCl_3$, 75 MHz): δ = 15.4 (CH_3), 70.9 (OCH_2), 121.2 (C), 127.0, 127.9, 128.1, 129.3, 130.1, 131.3 (CH_{Ar}), 133.9, 139.7 (C_{Ar}), 160.8 (CH), 195.9 (CO); IR (neat): $\tilde{\nu}$ = 3434, 3056, 2978, 2930, 2895, 1725, 1627 (w), 1656, 1614, 1596 (m), 1495 (w), 1445 (m), 1381 (w), 1299, 1277 (m), 1224 (s), 1175, 1143, 1082, 1014, 909, 836 (m), 798 (w), 763, 763 (m), 694 (s), 663, 643 (m), 606 (w) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) = 253 (19), 252 (M^+, 100), 224 (13), 223 (61), 178 (10), 167 (13), 165 (20), 146 (12), 105 (61), 102 (10), 77 (38); HRMS (EI): calcd. for $C_{17}H_{17}O_2$ $[M+H]^+$: 253.122300; Found: 253.122400.

General procedure for the synthesis of 4-hydroxybiphenyl-3-carboxylate (17a-n):

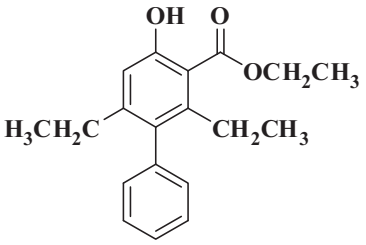
To a **CH_2Cl_2** solution (2 mL / 1.0 mmol of ***4***) of ***4*** (1.0 equiv.) was added ***16*** (1.0 equiv.) and subsequently **$TiCl_4$** (1.0 equiv.) at -78 °C. The temperature of the solution was allowed to warm to 20 °C during 14 h with stirring. To the solution was added saturated sodium bicarbonate solution (10 mL) and the organic and the aqueous layers were separated. The later was extracted with CH_2Cl_2 (3 x 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, *n*-heptane / EtOAc) to give product ***17***. The melting points given are uncorrected.

Methyl 2,6-diethyl-4-hydroxybiphenyl-3-carboxylate (17a):



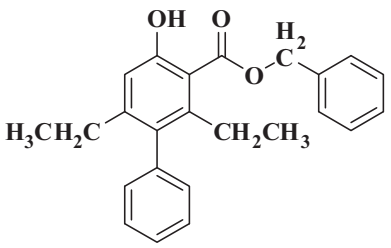
Starting with 1,3-bis(silyl enol ether), ***4a*** (500 mg, 1.91 mmol), 4-phenyl-5-(trimethylsilyloxy)hept-4-en-3-one, ***16a*** (528 mg, 1.91 mmol) and $TiCl_4$ (0.21 mL, 1.91 mmol), ***17a*** was obtained as a colorless crystalline solid (298 mg, 55 %), m.p = 88-90 ^{o}C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 0.84 (t, 3H, *J* = 7.4 Hz, CH_3), 0.93 (t, 3H, *J* = 7.5 Hz, CH_3), 2.13 (q, 2H, *J* = 7.5 Hz, CH_2), 2.57 (q, 2H, *J* = 7.4 Hz, CH_2), 4.36 (s, 3H, OCH_3), 6.74 (s, 1H, H_{Ar}), 7.05 (d, 2H, *J* = 7.8 Hz, H_{Ar}), 7.27-7.35 (m, 3H, H_{Ar}), 10.92 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 14.4, 15.8 (CH_3), 25.7, 27.9 (CH_2), 52.1 (OCH_3), 109.9 (C_{Ar}), 114.7 (CH_{Ar}), 126.7 (CH_{Ph}), 128.1 ($2CH_{Ph}$), 130.1 ($2CH_{Ph}$), 134.3, 140.1, 144.8, 150.1, 161.5 (C_{Ar}), 172.0 (C=O); IR (KBr): $\tilde{\nu}$ = 3058 (w), 2975 (m), 2874 (w), 1650, 1596 (m), 1487 (w), 1430, 1369, 1315, 1245 (m), 1214 (s), 1174, 1088, 1035, 967, 883, 810, 766 (m), 705 (s), 643, 574 (m) cm^{-1}; EI-MS (EI, 70 eV): m/z (%) = 284 (M^+, 27), 253 (21), 252 (100), 209 (18), 195 (4), 181 (5), 166 (8), 165 (14), 152 (7); HRMS (EI): calcd. for $C_{18}H_{20}O_3$ $[M]^+$: 284.140700; Found: 284.140644.

Ethyl 2,6-diethyl-4-hydroxybiphenyl-3-carboxylate (17b):



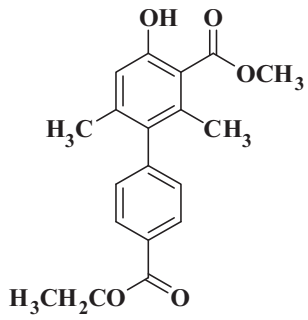
Starting with 1,3-bis(silyl enol ether), ***4b*** (600 mg, 2.18 mmol), 4-phenyl-5-(trimethylsilyloxy)hept-4-en-3-one, ***16a*** (603 mg, 2.18 mmol) and $TiCl_4$ (0.24 mL, 2.18 mmol), ***17b*** was obtained as a colorless crystalline solid (280 mg, 43 %), m.p = 102-103 ^{o}C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 0.86 (t, 3H, *J* = 7.4 Hz, CH_3), 0.93 (t, 3H, *J* = 7.5 Hz, CH_3), 1.33 (t, 3H, *J* = 7.2 Hz, CH_3), 2.12 (q, 2H, *J* = 7.5 Hz, CH_2), 2.60 (q, 2H, *J* = 7.4 Hz, CH_2), 4.36 (q, 2H, *J* = 7.2 Hz, OCH_2), 6.73 (s, 1H, H_{Ar}), 7.05 (d, 2H, *J* = 7.8 Hz, H_{Ar}), 7.24-7.35 (m, 3H, H_{Ar}), 11.04 (s, 1H, OH) ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 13.9, 14.5, 15.9 (CH_3), 25.7, 27.5 (CH_2), 61.5 (OCH_2), 110.0 (C_{Ar}), 114.7 (CH_{Ar}), 126.7 (CH_{Ph}), 128.1 ($2CH_{Ph}$), 130.1 ($2CH_{Ph}$), 134.2, 140.1, 144.8, 150.0, 161.6 (C_{Ar}), 171.6 (C=O); IR (KBr): $\tilde{\nu}$ = 3055 (w), 2974, 2873, 1644, 1594 (m), 1488 (w), 1439, 1371, 1311 (m), 1215 (s), 1088, 1012, 956, 874, 808 (m), 708 (s), 651, 573 (m) cm^{-1}; EI-MS (EI, 70 eV): m/z (%) = 298 (M^+, 24), 253 (22), 252 (100), 209 (15), 195 (4), 166 (7), 165 (13), 152 (6); HRMS (EI): calcd. for $C_{19}H_{22}O_3$ $[M]^+$: 298.156350; Found: 298.156405.

Benzyl 2,6-diethyl-4-hydroxybiphenyl-3-carboxylate (17c):



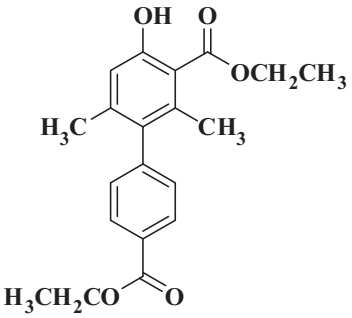
Starting with 1,3-bis(silyl enol ether), ***4c*** (600 mg, 1.78 mmol), 4-phenyl-5-(trimethylsilyloxy)hept-4-en-3-one, ***16a*** (492 mg, 1.78 mmol) and $TiCl_4$ (0.19 mL, 1.78 mmol), ***17c*** was obtained as a colorless crystalline solid (231 mg, 36 %), m.p = 65-66 ^{o}C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 0.72 (t, 3H, *J* = 7.4 Hz, CH_3), 0.89 (t, 3H, *J* = 7.5 Hz, CH_3), 2.09 (q, 2H, *J* = 7.5 Hz, CH_2), 2.54 (q, 2H, *J* = 7.4 Hz, CH_2), 5.29 (s, 2H, OCH_2), 6.72 (s, 1H, H_{Ar}), 6.99-7.31 (m, 10H, 2Ph), 10.93 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 14.5, 16.0 (CH_3), 25.6, 27.5 (CH_2), 67.6 (OCH_2), 109.9 (C_{Ar}), 114.7 (CH_{Ar}), 126.7 (CH_{Ph}), 128.1 ($2CH_{Ph}$), 128.6 ($2CH_{Ph}$), 128.7 (CH_{Ph}), 128.8 ($2CH_{Ph}$), 130.1 ($2CH_{Ph}$), 134.3, 134.9, 140.1, 144.9, 150.2, 161.7 (C_{Ar}), 171.4 (C=O); IR (KBr): $\widetilde{\nu}$ = 3027 (w), 2965, 2878 (m), 1705 (w), 1644 (s), 1594, 1494, 1439, 1378 (m), 1311 (s), 1254 (m), 1212 (s), 1174, 1087, 1035, 959, 880, 807 (m), 748, 705 (s), 654, 573 (m) cm^{-1}; EI-MS (EI, 70 eV): m/z (%) = 361 (10), 360 (M^+, 46), 342 (11), 269 (22), 253 (26), 252 (100), 251 (31), 165 (6), 152 (4), 91 (82), 29 (5); HRMS (EI): calcd. for $C_{24}H_{22}O_3$ $[M]^+$: 360.172000; Found: 360.172920.

4'-Ethyl 3-methyl 4-hydroxy-2,6-dimethylbiphenyl-3,4'-dicarboxylate (17d):



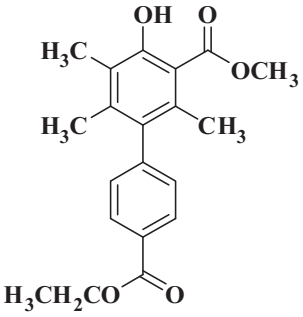
Starting with 1,3-bis(silyl enol ether), ***4a*** (500 mg, 1.91 mmol), ethyl 4-(4-oxo-2-(trimethylsilyloxy)pent-2-en-3-yl)benzoate, ***16b*** (612 mg, 1.91 mmol) and $TiCl_4$ (0.21 mL, 1.91 mmol), ***17d*** was obtained as colorless solid (376 mg, 60 %), m.p = 86-87 ^{o}C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.42 (t, 3H, *J* = 7.0 Hz, CH_3), 1.93 (s, 3H, CH_3), 2.17 (s, 3H, CH_3), 3.95 (s, 3H, OCH_3), 4.41 (q, 2H, *J* = 7.0 Hz, OCH_2), 6.78 (s, 1H, H_{Ar}), 7.18 (d, 2H, *J* = 8.5 Hz, H_{Ar}), 8.12 (d, 2H, *J* = 8.5 Hz, H_{Ar}), 11.05 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 14.3, 20.7, 21.7 (CH_3), 52.0 (OCH_3), 61.0 (OCH_2), 110.9 (C_{Ar}), 116.4 (CH_{Ar}), 129.1 (C_{Ar}), 129.7 ($2CH_{Ar}$), 129.8 ($2CH_{Ar}$), 134.0, 138.1, 143.3, 145.8, 161.2 (C_{Ar}), 166.4, 172.0 (C=O); IR (KBr): $\widetilde{\nu}$ = 2981, 2954, 1712 (w), 1659, 1607, 1440, 1351, 1321 (m), 1269 (s), 1175 (m), 1099 (s), 993, 907, 804 (m), 727 (s), 647 (m), 564 (w) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) = 328 (M^+, 25), 297 (23), 296 (100), 268 (11), 165 (11), 152 (11); HRMS (EI): calcd. for $C_{19}H_{20}O_5$ $[M]^+$: 328.130530; Found: 328.130469.

Diethyl 4-hydroxy-2,6-dimethylbiphenyl-3,4'-dicarboxylate carboxylate (17e):



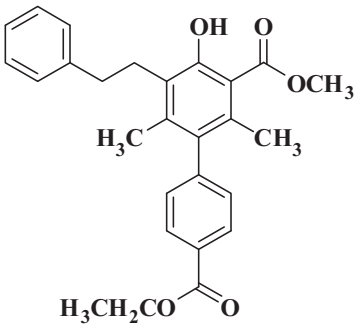
Starting with 1,3-bis(silyl enol ether), ***4b*** (500 mg, 1.82 mmol), ethyl 4-(4-oxo-2-(trimethylsilyloxy)pent-2-en-3-yl)benzoate, ***16b*** (583 mg, 1.82 mmol) and $TiCl_4$ (0.20 mL, 1.82 mmol), ***17e*** was obtained as colorless solid (280 mg, 45 %), m.p = 87-88 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.38 (t, 3H, *J* = 7.1 Hz, CH_3), 1.43 (t, 3H, *J* = 7.1 Hz, CH_3), 1.93 (s, 3H, CH_3), 2.19 (s, 3H, CH_3), 4.38 (q, 2H, *J* = 7.1 Hz, OCH_2), 4.44 (q, 2H, *J* = 7.1 Hz, OCH_2), 6.78 (s, 1H, H_{Ar}), 7.17 (d, 2H, *J* = 8.4 Hz, H_{Ar}), 8.12 (d, 2H, *J* = 8.4 Hz, H_{Ar}), 11.11 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 14.0, 14.2, 20.7, 21.6 (CH_3), 60.8, 61.4 (OCH_2), 110.9 (C_{Ar}), 116.2 (CH_{Ar}), 128.9 (C_{Ar}), 129.7 ($2CH_{Ar}$), 129.8 ($2CH_{Ar}$), 133.9, 138.0, 143.0, 145.7, 161.2 (C_{Ar}), 166.3, 171.5 (C=O); IR (KBr): $\tilde{\nu}$ = 2987, 2937, 1717 (w), 1651, 1598 (m), 1513 (w), 1443, 1371, 1313, 1271 (m), 1226 (s), 1178 (m), 1091 (s), 1019 (m), 964 (w), 856, 801 (m), 711 (s), 647, 597, 561 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) = 342 (M^+, 23), 297 (29), 296 (100), 268 (10), 165 (9), 152 (9); HRMS (EI): calcd. for $C_{20}H_{22}O_5$ $[M]^+$: 342.146180; Found: 342.146209.

4'-Ethyl 3-methyl 4-hydroxy-2,5,6-trimethylbiphenyl-3,4'-dicarboxylate (17f):



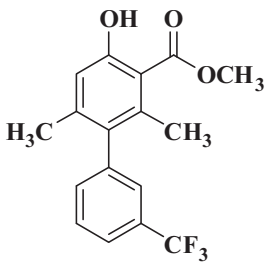
Starting with 1,3-bis(silyl enol ether), ***4d*** (600 mg, 2.18 mmol), ethyl 4-(4-oxo-2-(trimethylsilyloxy)pent-2-en-3-yl)benzoate, ***16b*** (698 mg, 2.18 mmol) and $TiCl_4$ (0.24 mL, 2.18 mmol), ***17f*** was obtained as colorless solid (320 mg, 43 %), m.p = 98-100 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.42 (t, 3H, *J* = 7.1 Hz, CH_3), 1.89 (s, 3H, CH_3), 2.11 (s, 3H, CH_3), 2.21 (s, 3H, CH_3), 3.94 (s, 3H, OCH_3), 4.41 (q, 2H, *J* = 7.1 Hz, OCH_2), 7.16 (d, 2H, *J* = 8.5 Hz, H_{Ar}), 8.09 (d, 2H, *J* = 8.5 Hz, H_{Ar}), 11.36 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 12.0, 14.4, 18.7, 20.8 (CH_3), 52.1 (OCH_3), 61.0 (OCH_2), 110.3, 122.5, 129.0 (C_{Ar}), 129.8 ($2CH_{Ar}$), 130.1 ($2CH_{Ar}$), 133.8, 134.7, 141.6, 147.0, 159.3 (C_{Ar}), 166.6, 172.7 (C=O); IR (KBr): $\tilde{\nu}$ = 2954, 2871 (w), 1714 (s), 1650, 1608 (m), 1565, 1504 (w), 1435, 1358, 1307, 1258 (m), 1220 (s), 1142 (m), 1096 (s), 1026, 968, 871 (m), 802, 714 (s), 644, 580 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) = 342 (M^+, 23), 311 (29), 310 (100), 309 (10), 265 (10), 267 (21), 237 (13), 209 (17), 195 (10), 166 (10), 165 (21), 152 (6), 132 (9); HRMS (EI): calcd. for $C_{20}H_{22}O_5$ $[M]^+$: 342.146180; Found: 342.146311.

4'-Ethyl3-methyl4-hydroxy-2,6-dimethyl-5-phenethylbiphenyl-3,4'-dicarboxylate (17g):



Starting with 1,3-bis(silyl enol ether), ***4j*** (500 mg, 1.37 mmol), ethyl 4-(4-oxo-2-(trimethylsilyloxy)pent-2-en-3-yl)benzoate, ***16b*** (439 mg, 1.37 mmol) and $TiCl_4$ (0.15 mL, 1.37 mmol), ***17g*** was obtained as colorless solid (207 mg, 35 %), m.p = 100-102 ^{o}C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.42 (t, 3H, *J* = 7.1 Hz, CH_3), 1.80 (s, 3H, CH_3), 2.12 (s, 3H, CH_3), 2.83 (t, 2H, *J* = 5.0 Hz, CH_2), 3.00 (t, 2H, *J* = 5.0 Hz, CH_2), 3.95 (s, 3H, OCH_3), 4.40 (q, 2H, *J* = 7.1 Hz, OCH_2), 7.17-7.30 (m, 7H, H_{Ar}), 8.09 (d, 2H, *J* = 8.5 Hz, H_{Ar}), 11.39 (s, 1H, OH); ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 14.4, 18.1, 20.9 (CH_3), 29.1, 35.1 (CH_2), 52.2 (OCH_3), 61.0 (OCH_2), 110.5 (C_{Ar}), 125.8 (CH_{Ph}), 126.2 (C_{Ar}), 128.3 (C_{Ar}), 128.5 ($2CH_{Ar}$), 129.0 ($2CH_{Ar}$), 129.9 ($2CH_{Ar}$), 130.0 ($2CH_{Ar}$), 134.1, 135.3, 141.4, 142.4, 147.0, 159.5 (C_{Ar}), 166.6, 172.7 (C=O); IR (KBr): $\tilde{\nu}$ = 3054, 2952, 2871 (w), 1711, 1645 (m), 1562 (w), 1495, 1437, 1363, 1268 (m), 1219 (s), 1143 (m), 1093 (s), 1022, 969, 877, 807, 753 (m), 699 (s), 628, 566 (m) cm^{-1}; EI-MS (EI, 70 eV): m/z (%) = 432 (M^+, 8), 385 (19), 384 (31), 383 (100), 355 (15), 309 (42), 266 (26), 251 (49), 207 (31), 179 (18), 178 (19), 165 (23), 91 (56), 29 (35); HRMS (ESI-TOF): calcd. for $C_{27}H_{29}O_5$ $[M+H]^+$: 433.200950; Found: 433.201420.

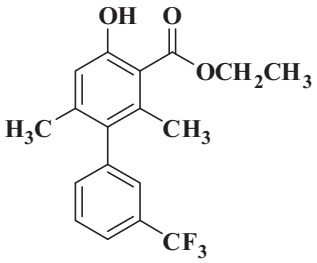
Methyl 4-hydroxy-2,6-dimethyl-3'-(trifluoromethyl)biphenyl-3-carboxylate (17h):



Starting with 1,3-bis(silyl enol ether), ***4a*** (600 mg, 2.30 mmol), 3-(3-(trifluoromethyl)phenyl)-4-(trimethylsilyloxy)pent-3-en-2-one, ***16c*** (727 mg, 2.30 mmol) and $TiCl_4$ (0.25 mL, 2.30 mmol), ***17h*** was obtained as white solid (320 mg, 43 %), m.p = 104-105 ^{o}C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.93 (s, 3H, CH_3), 2.17 (s, 3H, CH_3), 3.95 (s, 3H, OCH_3), 6.79 (s, 1H, H_{Ar}), 7.29 (d (br.), 1H, *J* = 7.5 Hz, H_{Ar}), 7.37 (s (br.), 1H, H_{Ar}), 7.55 (t (br.), 1H, *J* = 7.5, 7.8 Hz, H_{Ar}), 7.62 (d (br.), 1H, *J* = 7.8 Hz, H_{Ar}), 11.06 (s, 1H, OH); ^{19}F-NMR (282 MHz, $CDCl_3$): δ = -62.5; ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 20.9, 21.9 (CH_3), 52.2 (OCH_3), 110.9 (C_{Ar}), 116.6, 123.7 ($^{3}J_{C,F}$ = 3.4 Hz) (CH_{Ar}), 124.1 ($^{1}J_{C,F}$ = 271.3 Hz, CF_3), 126.5 ($^{3}J_{C,F}$ = 3.8 Hz), 129.1 (CH_{Ar}), 130.6 ($^{2}J_{C,F}$ = 31.6 Hz, C_{Ar}), 133.4 ($^{4}J_{C,F}$ = 1.6 Hz, CH_{Ar}), 133.5, 138.5, 141.7, 143.7, 161.4 (C_{Ar}), 172.2 (C=O); IR (KBr): $\tilde{\nu}$ = 3013, 2955 (w), 1651, 1597, 1444, 1357 (m), 1306 (s), 1229 (m), 1157 (s), 1108 (m), 1072 (s), 1008, 944, 860 (m), 804, 708 (s), 656, 578 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z

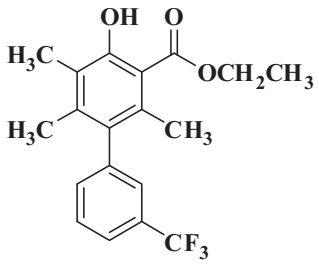
(%) = 324 (M^+, 28), 293 (24), 292 (100), 264 (18), 167 (7), 165 (11), 152 (7); HRMS (EI): calcd. for $C_{17}H_{16}F_3O_3$ $[M+H]^+$: 325.104610; Found: 325.104790.

Ethyl 4-hydroxy-2,6-dimethyl-3'-(trifluoromethyl)biphenyl-3-carboxylate (17i):



Starting with 1,3-bis(silyl enol ether), ***4b*** (500 mg, 1.82 mmol), 3-(3-(trifluoromethyl)phenyl)-4-(trimethylsilyloxy)pent-3-en-2-one, ***16c*** (576 mg, 1.82 mmol) and $TiCl_4$ (0.20 mL, 1.82 mmol), ***17i*** was obtained as white solid (215 mg, 35 %), m.p = 88-89 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.40 (t, 3H, *J* = 7.1 Hz, CH_3), 1.93 (s, 3H, CH_3), 2.19 (s, 3H, CH_3), 4.43 (q, 2H, *J* = 7.1 Hz, OCH_2), 6.79 (s, 1H, H_{Ar}), 7.28 (d (br.), 1H, *J* = 7.5 Hz, H_{Ar}), 7.36 (s (br.), 1H, H_{Ar}), 7.53 (t (br.), 1H, *J* = 7.5, 7.8 Hz, H_{Ar}), 7.60 (d (br.), 1H, *J* = 7.8 Hz, H_{Ar}), 11.14 (s, 1H, OH): ^{19}F-NMR (282 MHz, $CDCl_3$): δ = -62.5; ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 14.1, 20.9, 21.9 (CH_3), 61.7 (OCH_2), 111.1 (C_{Ar}), 116.6, 123.7 ($J_{C,F}$ = 3.6 Hz) (CH_{Ar}), 124.1 ($J_{C,F}$ = 271.8 Hz, CF_3), 126.6 ($J_{C,F}$ = 3.6 Hz), 129.7 (CH_{Ar}), 130.6 ($J_{C,F}$ = 32.4 Hz, C_{Ar}), 133.3 ($J_{C,F}$ = 1.5 Hz, CH_{Ar}), 133.5, 138.6, 141.7, 143.5, 161.5 (C_{Ar}), 171.8 (C=O); IR (KBr): $\tilde{\nu}$ = 3071, 2985, 2872 (w), 1650, 1595, 1467, 1400, 1349 (m), 1304, 1228, 1166, 1114 (s), 1065, 1007, 928, 874 (m), 804 (s), 761 (m), 709 (s), 655, 578 (m) cm^{-1}; EI-MS (EI, 70 eV): m/z (%) = 338 (M^+, 26), 293 (26), 292 (100), 264 (14), 263 (5), 167 (5), 165 (8), 152 (4); HRMS (EI): calcd. for $C_{18}H_{17}F_3O_3$ $[M]^+$: 338.112430; Found: 338.112362.

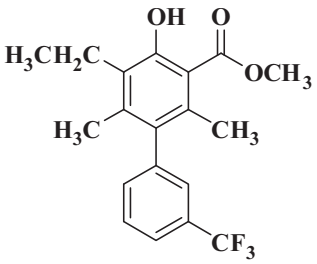
Methylethyl4-hydroxy-2,5,6-trimethyl-3'-(trifluoromethyl)biphenyl-3-carboxylate (17j):



Starting with 1,3-bis(silyl enol ether), ***4e*** (600 mg, 2.07 mmol), 3-(3-(trifluoromethyl)phenyl)-4-(trimethylsilyloxy)pent-3-en-2-one, ***16c*** (655 mg, 2.07 mmol) and $TiCl_4$ (0.22 mL, 2.07 mmol), ***17j*** was obtained as white solid (270 mg, 37 %), m.p = 100-102 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.32 (t, 3H, *J* = 7.2 Hz, CH_3), 1.82 (s, 3H, CH_3), 2.06 (s, 3H, CH_3), 4.35 (q, 2H, *J* = 7.2 Hz, OCH_2), 7.20 (d (br.), 1H, *J* = 7.4 Hz, H_{Ar}), 7.29 (s (br.), 1H, H_{Ar}), 7.45 (t (br.), 1H, *J* = 7.4, 7.7 Hz, H_{Ar}), 7.53 (d (br.), 1H, *J* = 7.7 Hz, H_{Ar}), 11.33 (s, 1H, OH); ^{19}F-NMR (282 MHz, $CDCl_3$): δ = -62.5; ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 11.9, 14.1, 18.7, 20.9 (CH_3), 61.6 (OCH_2), 110.6, 122.6 (C_{Ar}), 123.5 ($J_{C,F}$ = 3.5 Hz, CH_{Ar}), 124.1 ($J_{C,F}$ = 270.7 Hz, CF_3), 126.7 ($J_{C,F}$ = 4.0 Hz), 129.0 (CH_{Ar}), 130.9 ($J_{C,F}$ = 31.9 Hz), 133.2, (C_{Ar}), 133.4 ($J_{C,F}$ = 1.6 Hz, CH_{Ar}), 135.0, 141.6, 142.7, 159.4 (C_{Ar}), 172.2 (C=O); IR

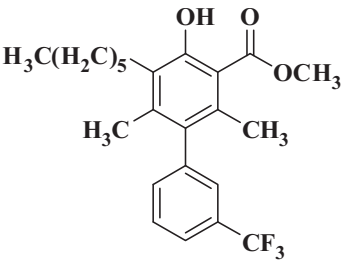
(KBr): $\tilde{\nu}$ = 3018, 2925, 2854 (w), 1642, 1596, 1492, 1435, 1379, 1332, 1220, 1160 (m), 1114, 1074 (s), 1030, 928, 869 (m), 802, 710 (s), 648, 580 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) = 352 (M^+, 31), 307 (29), 306 (100), 305 (61), 278 (26), 264 (9), 263 (34), 235 (9), 209 (5), 166 (7), 165 (11), 152 (3); HRMS (EI): calcd. for $C_{19}H_{19}F_3O_3$ $[M]^+$: 352.128080; Found: 352.128470.

Methyl5-ethyl-4-hydroxy-2,6-dimethyl-3'-(trifluoromethyl)biphenyl-3-carboxylate(17k):



Starting with 1,3-bis(silyl enol ether), ***4f*** (500 mg, 1.73 mmol), 3-(3-(trifluoromethyl)phenyl)-4-(trimethylsilyloxy)pent-3-en-2-one, ***16c*** (547 mg, 1.73 mmol) and $TiCl_4$ (0.19 mL, 1.73 mmol), ***17k*** was obtained as white solid (286 mg, 47 %), m.p = 113-115 ^oC. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.06 (t, 3H, *J* = 7.5 Hz, CH_3), 1.84 (s, 3H, CH_3), 2.03 (s, 3H, CH_3), 2.67 (q, 2H, *J* = 7.5 Hz, CH_2), 3.87 (s, 1H, OCH_3), 7.21 (d (br.), 1H, *J* = 7.6 Hz, H_{Ar}), 7.29 (s (br.), 1H, H_{Ar}), 7.46 (t (br.), 1H, *J* = 7.9, 7.6 Hz, H_{Ar}), 7.53 (d (br.), 1H, *J* = 7.9 Hz, H_{Ar}), 11.22 (s, 1H, OH); ^{19}F-NMR (282 MHz, $CDCl_3$): δ = -62.5; ^{13}C-NMR (62 MHz, $CDCl_3$): δ = 13.2, 17.9 (CH_3), 19.7 (CH_2), 20.8 (CH_3), 52.1 (OCH_3), 110.1, 123.5 ($J_{C,F}$ = 4.0 Hz, CH_{Ar}), 124.1 ($J_{C,F}$ = 270.6 Hz, CF_3), 126.6 ($J_{C,F}$ = 3.3 Hz), 128.7 (C_{Ar}), 129.0 (CH_{Ar}), 130.9 ($J_{C,F}$ = 32.1 Hz), 133.3 (C_{Ar}), 133.4 ($J_{C,F}$ = 1.1 Hz, CH_{Ar}), 135.1, 141.0, 142.7, 159.3 (C_{Ar}), 172.6 (C=O); IR (KBr): $\tilde{\nu}$ = 3064 (w), 2954 (m), 2852(w), 1650, 1596 (m), 1490 (w), 1439, 1360 (m), 1308, 1220 (s), 1159 (m), 1108 (s), 1036, 965 (m), 855 (w), 806 (s), 710, 651, 577 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) = 353 (9), 352 (M^+, 42), 321 (26), 320 (100), 293 (10), 292 (59), 277 (29), 263 (10), 179 (6),178 (6), 165 (14), 152 (4); HRMS (EI): calcd for $C_{19}H_{19}F_3O_3$ $[M]^+$: 352.128080; Found: 352.128383.

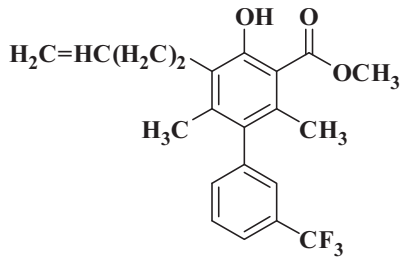
Methyl 5-hexyl-4-hydroxy-2,6-dimethyl-3'-(trifluoromethyl)biphenyl-3-carboxylate (17l):



Starting with 1,3-bis(silyl enol ether), ***4g*** (500 mg, 1.45 mmol), 3-(3-(trifluoromethyl)phenyl)-4-(trimethylsilyloxy)pent-3-en-2-one, ***16c*** (458 mg, 1.45 mmol) and $TiCl_4$ (0.16 mL, 1.45 mmol), ***17l*** was obtained as light yellowish solid (254 mg, 43 %), m.p = 96-97 ^oC. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 0.71 (t, 3H, *J* = 7.0 Hz, CH_3), 1.08-1.33 (m, 8H, $4CH_2$), 1.73 (s, 3H, CH_3), 1.92 (s, 3H, CH_3), 2.52 (t, 2H, *J* = 6.9 Hz, CH_2), 3.76 (s, 1H, OCH_3), 7.21 (d (br.), 1H, *J* = 7.5 Hz, H_{Ar}), 7.29 (s (br.), 1H, H_{Ar}), 7.46 (t (br.), 1H, *J* = 7.8, 7.5 Hz, H_{Ar}), 7.54 (d (br.), 1H, *J* = 7.8 Hz, H_{Ar}), 11.10 (s, 1H, OH); ^{19}F-NMR (282 MHz, $CDCl_3$): δ = -

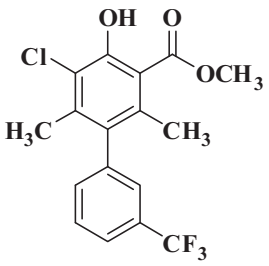
62.5; ^{13}C-NMR (62 MHz, $CDCl_3$): δ = 15.3, 19.4, 22.1 (CH_3), 23.8, 27.8, 30.2, 30.9, 33.0 (CH_2), 53.0 (OCH_3), 111.7 (C_{Ar}), 124.7 ($J_{C,F}$ = 3.8 Hz, CH_{Ar}), 125.6 ($J_{C,F}$ = 270.8 Hz, CF_3), 127.8 ($J_{C,F}$ = 3.8 Hz, CH_{Ar}), 128.8 (C_{Ar}), 130.2 (CH_{Ar}), 132.5 ($J_{C,F}$ = 32.3 Hz), 134.5 (C_{Ar}), 134.6 ($J_{C,F}$ = 1.5 Hz, CH_{Ar}), 136.3, 142.4, 144.0, 160.6 (C_{Ar}), 173.8 (C=O); IR (KBr): $\tilde{\nu}$ = 2955, 2857, 1933 (w), 1703, 1656, 1592, 1490, 1437, 1317, 1215 (m), 1123, 1071 (s), 1002, 958, 903, 805 (m), 704 (s), 652, 579 (m) cm^{-1}; EI-MS (EI, 70 eV): m/z (%) = 409 (11), 408 (M^+, 48), 376 (18), 361 (45), 359 (41), 347 (24), 333 (20), 319 (20), 306 (100), 305 (94), 278 (16), 263 (14), 165 (11); HRMS (EI): calcd. for $C_{23}H_{27}F_3O_3$ $[M]^+$: 408.190680; Found: 408.190957.

Methyl5-(but-3-enyl)-4-hydroxy-2,6-dimethyl-3'-(trifluoromethyl)biphenyl-3-carboxylate (17m):



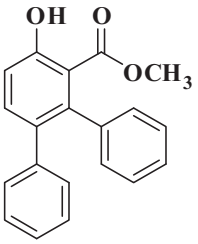
Starting with 1,3-bis(silyl enol ether), ***4i*** (600 mg, 1.90 mmol), 3-(3-(trifluoromethyl)phenyl)-4-(trimethylsilyloxy)pent-3-en-2-one, ***16c*** (601 mg, 1.90 mmol) and $TiCl_4$ (0.20 mL, 1.90 mmol), ***17m*** was obtained as light yellowish solid (316 mg, 44 %), m.p = 86-87 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 1.84 (s, 3H, CH_3), 2.03 (s, 3H, CH_3), 2.20 (q (br.), 2H, J = 6.7 Hz, CH_2), 2.74 (t, 2H, J = 7.7 Hz, CH_2), 3.87 (s, 3H, OCH_3), 4.88-5.03 (m, 2H, =CH_2), 5.79-5.93 (m, 1H, =CH), 7.21 (d (br.), 1H, J = 7.5 Hz, H_{Ar}), 7.29 (s (br.), 1H, H_{Ar}), 7.47 (t (br.), 1H, J = 7.5, 7.7 Hz, H_{Ar}), 7.53 (d (br.), 1H, J = 7.7 Hz, H_{Ar}), 11.24 (s, 1H, OH); ^{19}F-NMR (282 MHz, $CDCl_3$): δ = -62.5; ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 18.3, 20.9 (CH_3), 26.2, 32.9 (CH_2), 52.1 (OCH_3), 110.6 (C_{Ar}), 114.5 (=CH_2), 123.5 ($J_{C,F}$ = 3.8 Hz, CH_{Ar}), 124.1 ($J_{C,F}$ = 271.2 Hz, CF_3), 126.5 (C_{Ar})), 126.7 ($J_{C,F}$ = 3.8 Hz), 129.0 (CH_{Ar}), 131.0 ($J_{C,F}$ = 31.8 Hz), 133.4 (C_{Ar}), 133.5 ($J_{C,F}$ = 3.2 Hz, CH_{Ar}), 135.1 (C_{Ar}), 138.6 (=CH), 141.3, 142.7, 159.5 (C_{Ar}), 172.6 (C=O); IR (KBr): $\tilde{\nu}$ = 3075, 2953, 1731 (w), 1655, 1591, 1439 (m), 1317 (s), 1214 (m), 1122 (s), 1071, 1001 (m), 908 (s), 849, 806, 758, 708, 652 (m), 588 (w) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) = 378 (M^+, 8), 338 (5), 337 (25), 307 (3), 306 (19), 305 (100), 277 (4), 234 (2), 233 (4), 209 (3), 165 (9), 152 (2); HRMS (EI): calcd. for $C_{21}H_{21}F_3O_3$ $[M]^+$: 378.143730; Found: 378.143781.

Methyl5-chloro-4-hydroxy-2,6-dimethyl-3'-(trifluoromethyl)biphenyl-3-carboxylate (17n):



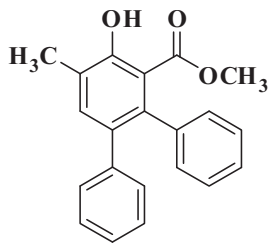
Starting with 1,3-bis(silyl enol ether), ***4k*** (500 mg, 1.69 mmol), 3-(3-(trifluoromethyl)phenyl)-4-(trimethylsilyloxy)pent-3-en-2-one, ***16c*** (535 mg, 1.69 mmol) and $TiCl_4$ (0.18 mL, 1.69 mmol), ***17n*** was obtained as light yellowish crystalline solid (194 mg, 32 %), m.p = 92-94 ^oC. ^1H-NMR (250 MHz, $CDCl_3$): δ = 1.97 (s, 3H, CH_3), 2.03 (s, 3H, CH_3), 3.90 (s, 3H, OCH_3), 7.21 (d (br.), 1H, ^3J = 6.7 Hz, H_{Ar}), 7.29 (s (br.), 1H, H_{Ar}), 7.45 (t (br.), 1H, ^3J = 6.7, 7.2 Hz, H_{Ar}), 7.54 (d (br.), 1H, ^3J = 7.2 Hz, H_{Ar}), 11.38 (s, 1H, OH); ^{19}F-NMR (282 MHz, $CDCl_3$): δ = -62.5; ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 18.5, 19.7 (CH_3), 51.5 (OCH_3), 113.0 (C_{Ar}), 122.9 ($J_{C,F}$ = 271.1 Hz, CF_3), 123.4 ($J_{C,F}$ = 3.6 Hz), 126.8 ($J_{C,F}$ = 3.8 Hz) (CH_{Ar}), 128.3 (C_{Ar}), 128.4 (CH_{Ar}), 130.3 ($J_{C,F}$ = 31.9 Hz), 132.9 (C_{Ar}), 133.6 ($J_{C,F}$ = 1.6 Hz, CH_{Ar}), 135.3, 140.1, 140.5, 155.6 (C_{Ar}), 170.8 (C=O); IR (KBr): $\tilde{\nu}$ = 3066, 2961, 2852 (w), 1650, 1587, 1490, 1403, 1303, 1224, 1175 (m), 1120, 1069 (s), 1009, 904 (m), 806, 702 (s), 649, 544 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) = 358 (M^+, ^{35}Cl, 25), 328 (36), 327 (27), 326 (100), 235 (6), 165 (13), 153 (4), 152 (2); HRMS (EI): calcd. for $C_{17}H_{14}ClF_3O_3$ $[M]^+$: 358.057810; Found: 358.057378.

Methyl 5,6-diphenylsalicylate (20a).



Starting with ***19*** (0.378 g, 1.5 mmol) and ***4a*** (0.429 g, 1.65 mmol), ***20a*** was isolated after chromatography (silica gel, n-heptane/EtOAc) as a pale yellowish solid (0.319 g, 70%), m.p = 119-121 °C. ^1H-NMR (300 MHz, $CDCl_3$): δ = 3.32 (s, 3H, OCH_3), 6.83–6.90 (m, 4H, CH_{Ar}), 7.00-7.10 (m, 7H, CH_{Ar}), 7.35 (d, J = 8.9 Hz, 1H, CH_{Ar}), 10.32 (s, 1H, OH; ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 52.0 (OCH_3), 113.5 (C_{Ar}), 116.6, 126.0, 126.3, 127.1, 127.5, 129.7, 129.9 (CH_{Ar}), 134.0 (C_{Ar}), 135.9 (CH_{Ar}), 140.6, 140.9, 142.1 (C_{Ar}), 160.5 (COH), 171.7 (CO); IR (neat): $\tilde{\nu}$ = 3052, 2922, 2851, 1814, 1738 (w), 1664 (s), 1590, 1493 (m), 1435, 1317 (s), 1259 (m), 1216 (s), 1141, 1094, 1073 (m), 1024 (w), 960, 901, 847, 813 (m), 748 (s), 720 (m), 695 (s), 640, 598, 576, 547 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) = 304 (M^+, 34), 273 (21), 272 (100), 244 (10), 215 (40), 107 (12); HRMS (EI): calcd. for $C_{20}H_{17}O_3$ $[M+H]^+$: 305.117200; Found: 305.117500.

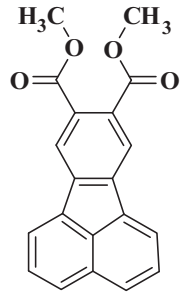
Methyl 3-methyl-5,6-diphenylsalicylate (20b):



Starting with ***19*** (0.378 g,1.5 mmol) and ***4d*** (0.453 g,1.65 mmol), ***20b*** was isolated after chromatography (silica gel, n-heptane/EtOAc) as a white solid (0.382 g, 80%), m.p = 150-152 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 2.20 (s, 3H, CH3), 3.22 (s, 3H, OCH3), 6.72–6.80 (m, 4H, CHAr), 6.88–6.97 (m, 6H, CHAr), 7.14 (s, 1H, CHAr), 10.47 (s, 1H, OH) ; ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 15.9 (CH3), 51.7 (OCH3), 112.7, 125.6 (CAr), 125.9, 126.1, 127.1, 127.5, 129.7, 129.9 (CHAr), 133.3 (CAr), 136.9 (CHAr), 139.5, 140.9, 141.1 (CAr), 158.4 (COH), 172.0 (CO); IR (neat): $\tilde{\nu}$ = 3071, 3021 (w), 2920 (m), 2851 (w), 1665, 1653 (m), 1607 (w), 1568, 1492 (w), 1436, 1404, 1377, 1338, 1301, 1237, 1209, 1156, 1070, 1014, 984 (m), 917 (w), 902 (m), 884, 842 (w), 811, 772 (m), 757, 698 (s), 645, 613, 563 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) = 319 (9), 318 (M^+, 38), 287 (23), 286 (100), 285 (41), 257 (12), 229 (13), 228 (14), 215 (14); HRMS (EI): calcd. for $C_{21}H_{19}O_3$ $[M]^+$: 319.132900; Found: 319.132900.

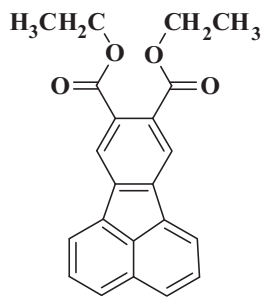
7.4 Synthesis of 8,9-Disubstituted Fluoranthenes by Domino Twofold Heck / Electrocyclization / Dehydrogenation of 1,2-Dibromoacenaphthylene.

Dimethyl fluoranthene-8,9-dicarboxylate (4a):



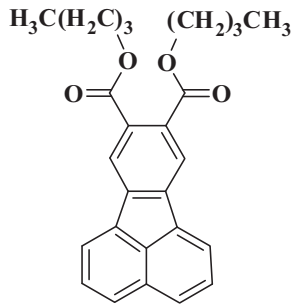
Starting with 1,2-dibromoacenaphthylene ***2*** (310 mg, 1.0 mmol) and methyl acrylate ***3a***, ***4a*** was isolated as a brownish viscous oil (216 mg, 68 %). ^{1}H-NMR (250 MHz, 300 K, $CDCl_3$): δ = 3.84 (s, 6H, 2 OCH_3), 7.51 (dd, 2H, *J* = 6.9, 8.0 Hz, H_{Ar}), 7.76 (d, 2H, *J* = 8.0 Hz, H_{Ar}), 7.83 (d, 2H, *J* = 6.9 Hz, H_{Ar}), 8.06 (s, 2H, H_{Ar}); ^{13}C-NMR (63 MHz, 300 K, $CDCl_3$): δ = 52.7 (OCH_3), 121.7, 121.9, 128.0, 128.2 (CH_{Ar}), 129.9, 130.9, 133.0, 135.0, 141.4 (C_{Ar}), 168.4 (C=O); IR (Neat): $\tilde{\nu}$ = 3038, 2947, 2850 (w), 1715 (s), 1650, 1614 (m), 1486 (w), 1435 (m), 1372 (w), 1326 (m), 1235, 1122 (s), 1053, 975, 932, 888, 821 (m), 769 (s), 666, 619, 541 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 319 (15), 318 (M^+, 68), 288 (21), 287 (100), 244 (7), 228 (8), 201 (21), 200 (30), 188 (18), 143 (11), 100 (9); HRMS (ESI-TOF): calcd. for $C_{20}H_{15}O_4$ $[M+H]^+$: 319.096500; Found: 319.09600.

Diethyl fluoranthene-8,9-dicarboxylate (4b):



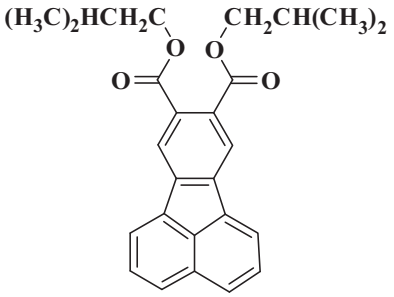
Starting with 1,2-dibromoacenaphthylene ***2*** (310 mg, 1.0 mmol) and ethyl acrylate ***3b***, ***4b*** was isolated as a brownish viscous oil (253 mg, 73 %). ^{1}H-NMR (300 MHz, 298 K, $CDCl_3$): δ = 1.32 (t, 6H, *J* = 7.1 Hz, $2CH_3$), 4.35 (q, 4H, *J* = 7.1 Hz, $2OCH_2$), 7.55 (dd, 2H, *J* = 7.1, 8.2 Hz, H_{Ar}), 7.80 (d, 2H, *J* = 8.2 Hz, H_{Ar}), 7.89 (d, 2H, *J* = 7.1 Hz, H_{Ar}), 8.10 (s, 2H, H_{Ar}); ^{13}C-NMR (75 MHz, 298 K, $CDCl_3$): δ = 14.2 (CH_3), 61.7 (OCH_2), 121.6, 121.9, 127.9, 128.1 (CH_{Ar}), 129.9, 131.4, 133.1, 135.1, 141.3 (C_{Ar}), 168.0 (C=O); IR (Neat): $\tilde{\nu}$ = 3047, 2976, 2868 (w), 1708 (s), 1609, 1562, 1460 (w), 1421, 1365, 1324 (m), 1240 (s), 1173, 1117, 1055, 1014, 973, 910, 822 (m), 768 (s), 733 (m), 675 (m), 621, 547 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 347 (16), 346 (M^+, 59), 301 (13), 274 (23), 273 (100), 229 (8), 201 (17), 200 (34), 189 (29), 188 (12), 100 (9), 23 (8); HRMS (EI): calcd. for $C_{22}H_{18}O_4$ $[M]^+$: 346.119960; Found: 346.119786.

Dibutyl fluoranthene-8,9-dicarboxylate (4c):



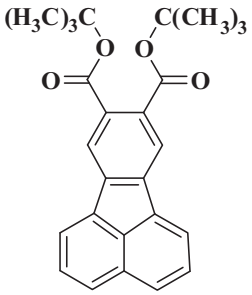
Starting with 1,2-dibromoacenaphthylene ***2*** (310 mg, 1.0 mmol) and *n*-butyl acrylate ***3c***, ***4c*** was isolated as a brownish viscous oil (310 mg, 77 %). ^{1}H-NMR (250 MHz, 300 K, $CDCl_3$): δ = 0.91 (t, 6H, *J* = 7.3 Hz, $2CH_3$), 1.39 (m, 4H, $2CH_2$), 1.70 (m, 4H, $2CH_2$), 4.29 (t, 4H, *J* = 6.7 Hz, $2OCH_2$), 7.57 (dd, 2H, *J* = 6.9, 8.1 Hz, H_{Ar}), 7.79 (d, 2H, *J* = 8.1 Hz, H_{Ar}), 7.90 (d, 2H, *J* = 6.9 Hz, H_{Ar}), 8.11 (s, 2H, H_{Ar}); ^{13}C-NMR (63 MHz, 300 K, $CDCl_3$): δ = 13.8 (CH_3), 19.2, 30.7 (CH_2), 65.6 (OCH_2), 121.6, 121.9, 127.9, 128.1 (CH_{Ar}), 129.9, 131.4, 133.0, 135.0, 141.3 (C_{Ar}), 168.1 (C=O); IR (Neat): $\tilde{\nu}$ = 3047 (w), 2956 (m), 2871 (w), 1714 (s), 1614, 1560 (w), 1458, 1420, 1386, 1322 (m), 1239 (s), 1183 (m), 1118, 1096 (s), 1050, 1006, 942, 901 (m), 821 (m), 769 (s), 688, 649, 613, 545 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 403 (10), 402 (M^+, 25), 346 (12), 329 (15), 290 (40), 274 (31), 273 (100), 272 (28), 246 (35), 229 (16), 228 (15), 201 (14), 200 (23), 189 (20), 100 (11), 57 (9), 41 (19), 29 (23); HRMS (EI): calcd. for $C_{26}H_{26}O_4$ $[M]^+$: 402.182560; Found: 402.182802.

Diisobutyl fluoranthene-8,9-dicarboxylate (4d):



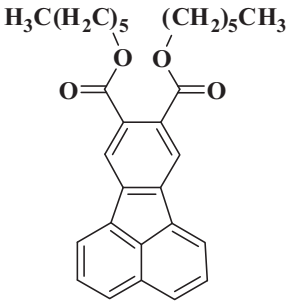
Starting with 1,2-dibromoacenaphthylene ***2*** (310 mg, 1.0 mmol) and *iso*-butyl acrylate ***3d***, ***4d*** was isolated as a light brownish solid (326 mg, 81 %), m.p = 95-97 °C. ^{1}H-NMR (250 MHz, 300 K, $CDCl_3$): δ = 0.95 (d, 12H, *J* = 6.7 Hz, $4CH_3$), 2.02 (m, 2H, 2CH), 4.07 (d, 4H, *J* = 6.7 Hz, $2OCH_2$), 7.55 (dd, 2H, *J* = 7.0, 7.9 Hz, H_{Ar}), 7.80 (d, 2H, *J* = 7.9 Hz, H_{Ar}), 7.89 (d, 2H, *J* = 7.0 Hz, H_{Ar}), 8.10 (s, 2H, H_{Ar}); ^{13}C-NMR (75 MHz, 300 K, $CDCl_3$): δ = 19.3 (CH_3), 27.8 (CH), 71.9 (OCH_2), 121.6, 121.9, 128.0, 128.2 (CH_{Ar}), 129.9, 131.5, 133.0, 135.1, 141.3 (C_{Ar}), 168.1 (C=O); IR (Neat): $\tilde{\nu}$ = 3044, 2959, 2871 (w), 1709 (s), 1651, 1613, 1557 (w), 1459, 1420, 1374, 1324 (m), 1254, 1116, 1051 (s), 981, 945, 902 (m), 824, 773 (s), 675, 613, 544 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 403 (10), 402 (M^+, 27), 346 (13), 291 (16), 290 (48), 274 (34), 273 (100), 272 (14), 246 (23), 229 (12), 228 (9), 201 (37), 200 (48), 199 (15), 189 (42), 100 (7), 57 (11), 41 (25), 29 (14); HRMS (EI): calcd. for $C_{26}H_{26}O_4$ $[M]^+$: 402.182560; Found: 402.182562.

Di-tert-butyl fluoranthene-8,9-dicarboxylate (4e):



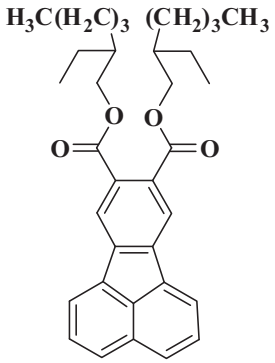
Starting with 1,2-dibromoacenaphthylene ***2*** (310 mg, 1.0 mmol) and *tert*-butyl acrylate ***3e***, ***4e*** was isolated as a light brownish crystalline solid (332 mg, 82 %), m.p = 162-164 °C. ^{1}H-NMR (300 MHz, 298 K, $CDCl_3$): δ = 1.57 (s, 18H, $6CH_3$), 7.57 (dd, 2H, *J* = 6.8, 8.0 Hz, H_{Ar}), 7.80 (d, 2H, *J* = 8.0 Hz, H_{Ar}), 7.91 (d, 2H, *J* = 6.8 Hz, H_{Ar}), 8.04 (s, 2H, H_{Ar}); ^{13}C-NMR (63 MHz, 298 K, $CDCl_3$): δ = 28.1 (CH_3), 81.8 (C), 121.4, 121.8, 127.7, 128.1 (CH_{Ar}), 129.9, 133.1, 133.2, 135.4, 140.8 (C_{Ar}), 167.2 (C=O); IR (Neat): $\tilde{\nu}$ = 3051, 2980 (w), 1704 (m), 1453, 1391, 1257, 1160 (w), 1057, 971 (m), 846, 769 (s), 622, 547 (m) cm^{-1}; EI-MS (EI, 70 eV): *m/z* (%) = 403 (20), 402 (M^+, 79), 347 (8), 346 (32), 291 (63), 290 (100), 274 (19), 273 (84), 272 (63), 246 (75), 229 (22), 228 (24), 201 (35), 200 (73), 189 (23), 100 (19), 57 (15), 41 (20); HRMS (EI): calcd. for $C_{26}H_{26}O_4$ $[M]^+$: 402.182560; Found: 402.183102.

Dihexyl fluoranthene-8,9-dicarboxylate (4f):



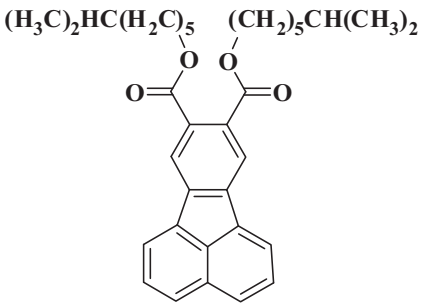
Starting with 1,2-dibromoacenaphthylene ***2*** (310 mg, 1.0 mmol) and *n*-hexyl acrylate ***3f***, ***4f*** was isolated as a brownish viscous oil (316 mg, 69 %). ^{1}H-NMR (250 MHz, 300 K, $CDCl_3$): δ = 0.81 (t, 6H, *J* = 6.9 Hz, $2CH_3$), 1.21-1.38 (m, 12H, $6CH_2$), 1.63-1.74 (m, 4H, $2CH_2$), 4.26 (t, 4H, *J* = 6.8 Hz, $2OCH_2$), 7.50 (dd, 2H, *J* = 7.0, 8.1 Hz, H_{Ar}), 7.76 (d, 2H, *J* = 8.1 Hz, H_{Ar}), 7.82 (d, 2H, *J* = 7.0 Hz, H_{Ar}), 8.04 (s, 2H, H_{Ar}); ^{13}C-NMR (63 MHz, 300 K, $CDCl_3$): δ = 14.0 (CH_3), 22.6, 25.7, 28.6, 31.5 (CH_2), 65.9 (OCH_2), 121.5, 121.8, 127.9, 128.1 (CH_{Ar}), 129.8, 131.4, 133.0, 135.0, 141.2 (C_{Ar}), 168.0 (C=O); IR (Neat): $\tilde{\nu}$ = 3047 (w), 2926, 2856 (m), 1716 (s), 1652, 1615, 1559 (w), 1458, 1420, 1322 (m), 1240 (s), 1183, 1119, 1052, 1006, 901, 822 (m), 770 (s), 725, 676, 613, 545 (m) cm^{-1}; EI-MS (EI, 70 eV): *m/z* (%) = 459 (10), 458 (M^+, 28), 374 (15), 363 (13), 290 (40), 274 (28), 273 (100), 272 (29), 258 (82), 246 (25), 230 (36), 209 (33), 203 (40), 189 (25), 101 (19), 56 (51), 43 (85); HRMS (EI): calcd. for $C_{30}H_{34}O_4$ $[M]^+$: 458.245160; Found: 458.245393.

Bis(2-ethylhexyl) fluoranthene-8,9-dicarboxylate (4g):



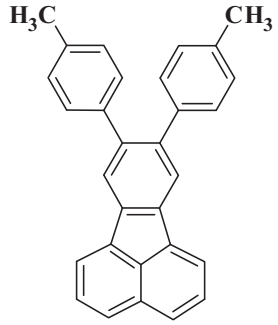
Starting with 1,2-dibromoacenaphthylene ***2*** (310 mg, 1.0 mmol) and 2-ethyl-hexyl acrylate ***3g***, ***4g*** was isolated as a light brownish viscous oil (365 mg, 71 %). ^{1}H-NMR (250 MHz, 300 K, $CDCl_3$): δ = 0.83-0.89 (m, 12H, $4CH_3$), 1.23-1.44 (m, 16H, $8CH_2$), 1.62-1.70 (m, 2H, 2CH), 4.20 (m, 4H, $2OCH_2$), 7.57 (dd, 2H, *J* = 7.0, 8.1 Hz, H_{Ar}), 7.81 (d, 2H, *J* = 8.1 Hz, H_{Ar}), 7.89 (d, 2H, *J* = 7.0 Hz, H_{Ar}), 8.09 (s, 2H, H_{Ar}); ^{13}C-NMR (75 MHz, 298 K, $CDCl_3$): δ = 11.0, 14.1 (CH_3), 23.0, 23.8, 29.0, 30.4 (CH_2), 38.8 (CH), 68.3 (OCH_2), 121.6, 121.8, 128.0, 128.2 (CH_{Ar}), 129.9, 131.6, 133.1, 135.1, 141.3 (C_{Ar}), 168.1 (C=O); IR (Neat): $\tilde{\nu}$ = 3046 (w), 2926, 2857 (m), 1716 (s), 1615, 1560 (w), 1458, 1420, 1379, 1322 (m), 1238 (s), 1183, 1118, 1098, 1051, 1006, 959, 900, 821 (m), 769 (s), 728, 689, 613, 544 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 515 (10), 514 (M^+, 50), 403 (38), 291 (61), 290 (85), 274 (68), 273 (100), 272 (53), 246 (77), 244 (36), 229 (39), 228 (44), 200 (70), 189 (13), 99 (25), 57 (35), 43 (62), 41 (22); HRMS (EI): calcd. for $C_{34}H_{42}O_4$ $[M]^+$: 514.307760; Found: 514.308599.

Bis(6-methylheptyl) fluoranthene-8,9-dicarboxylate (4h):



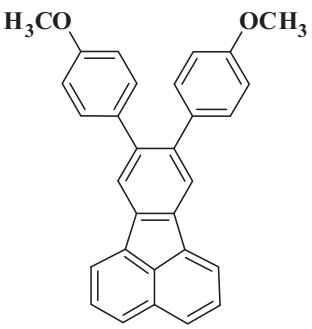
Starting with 1,2-dibromoacenaphthylene ***2*** (310 mg, 1.0 mmol) and *iso*-octyl acrylate ***3h***, ***4h*** was isolated as a light brownish viscous oil (335 mg, 65 %). ^{1}H-NMR (300 MHz, 298 K, $CDCl_3$): δ = 0.73-1.78 (m, 30H, $4CH_3$, 2CH, $8CH_2$), 4.29 (m, 4H, $2OCH_2$), 7.58 (dd, 2H, *J* = 7.1, 8.0 Hz, H_{Ar}), 7.83 (d, 2H, *J* = 8.0 Hz, H_{Ar}), 7.91 (d, 2H, *J* = 7.1 Hz, H_{Ar}), 8.12 (s, 2H, H_{Ar}); ^{13}C-NMR (63 MHz, 300 K, $CDCl_3$): δ = 15.3 (CH_3), 22.6, 23.8, 25.1 (CH_2), 29.1 (CH), 46.6 (CH_2), 66.2 (OCH_2), 121.6, 121.9, 127.9, 128.0 (CH_{Ar}), 129.9, 131.4, 133.1, 135.1, 141.3 (C_{Ar}), 168.0 (C=O); IR (Neat): $\tilde{\nu}$ = 3046 (w), 2954, 2869 (m), 1716 (s), 1614, 1562 (w), 1459, 1420, 1380, 1323 (m), 1253, 1239 (s), 1183, 1119, 1098, 1051, 1006, 965, 902, 821 (m), 770 (s), 649, 545 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 515 (8), 514 (M^+, 20), 403 (13), 402 (15), 291 (41), 290 (68), 274 (57), 273 (100), 272 (33), 246 (27), 229 (19), 228 (14), 200 (30), 189 (36), 71 (42), 57 (54), 43 (39), 41 (29); HRMS (EI): calcd. for $C_{34}H_{42}O_4$ $[M]^+$: 514.307760; Found: 514.306297.

8,9-Dip-tolylfluoranthene (4i):



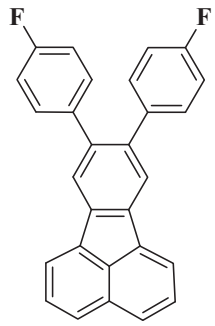
Starting with 1,2-dibromoacenaphthylene ***2*** (310 mg, 1.0 mmol) and *p*-methyl styrene ***3i***, ***4i*** was isolated as a brownish viscous oil (252 mg, 66 %). ^{1}H-NMR (300 MHz, 300 K, $CDCl_3$): δ = 2.32 (s, 6H, $2CH_3$), 7.14 (d, 4H, *J* = 7.9 Hz, H_{Ar}), 7.43-7.54 (m, 6H, H_{Ar}), 7.70 (d, 2H, *J* = 8.0 Hz, H_{Ar}), 7.75 (d, 2H, *J* = 6.8 Hz, H_{Ar}), 8.00 (s, 2H, H_{Ar}); ^{13}C-NMR (63 MHz, 298 K, $CDCl_3$): δ = 21.3 (CH_3), 121.4, 121.8, 126.6, 127.7, 128.1, 129.5 (CH_{Ar}), 129.7, 129.9, 133.1, 133.2, 135.4, 138.1, 140.8 (C_{Ar}); IR (Neat): $\tilde{\nu}$ = 3042, 2918, 2851, 2730, 1773 (w), 1713, 1602, 1511, 1427, 1377, 1305, 1259, 1178, 1092 (m), 1014 (s), 958, 906 (m), 817, 767 (s), 729, 671, 611, 533 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 383 (32), 382 (M^+, 100), 367 (20), 366 (16), 365 (12), 363 (15), 352 (27), 326 (11), 191 (13), 183 (23), 182 (25), 176 (28), 175 (20); HRMS (EI): calcd. for $C_{30}H_{22}$ $[M]^+$: 382.171600; Found: 382.171644.

8,9-Bis(4-methoxyphenyl)fluoranthene (4j):



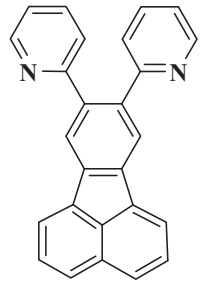
Starting with 1,2-dibromoacenaphthylene ***2*** (310 mg, 1.0 mmol) and p-methoxy styrene ***3j***, ***4j*** was isolated as a dark yellowish viscous oil (307 mg, 74 %). ^{1}H-NMR (300 MHz, 298 K, $CDCl_3$): δ = 3.74 (s, 6H, $2OCH_3$), 6.74 (d, 4H, *J* = 8.7 Hz, H_{Ar}), 7.11 (d, 4H, *J* = 8.7 Hz, H_{Ar}), 7.57 (dd, 2H, *J* = 6.9, 8.2 Hz, H_{Ar}), 7.79 (d, 2H, *J* = 8.2 Hz, H_{Ar}), 7.84 (s, 2H, H_{Ar}), 7.87 (d, 2H, *J* = 6.9 Hz, H_{Ar}); ^{13}C-NMR (63 MHz, 298 K, $CDCl_3$): δ = 55.2 (OCH_3), 113.4, 120.0, 123.7, 126.6, 128.0 (CH_{Ar}), 130.0 (C_{Ar}), 130.9 (CH_{Ar}) 133.0, 134.5, 136.8, 138.3, 139.5, 158.2 (CH_{Ar}); IR (Neat): $\tilde{\nu}$ = 3041, 2921, 2849, 1771 (w), 1712, 1681, 1599, 1510, 1460, 1421, 1365, 1303 (m), 1244, 1166 (s), 1106 (m), 1023, 821, 772 (s), 694, 633 (m), 537 (s) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 415 (29), 414 (M^+, 100), 326 (15), 316 (19), 314 (12), 286 (18), 285 (16), 207 (12), 181 (11), 163 (12), 152 (9), 151 (9), 135 (75), 77 (13), 71 (15), 57 (22), 44 (30), 43 (25), 41 (14); HRMS (EI): calcd. for $C_{30}H_{22}O_2$ $[M]^+$: 414.161430; Found: 414.161245.

8,9-Bis(4-fluorophenyl)fluoranthene (4k):



Starting with 1,2-dibromoacenaphthylene ***2*** (310 mg, 1.0 mmol) and *p*-fluoro styrene ***3k***, ***4k*** was isolated as a yellowish crystalline solid (230 mg, 59 %), m.p = 139-141 °C. ^{1}H-NMR (300 MHz, 298 K, $CDCl_3$): δ = 6.84-6.89 (m, 4H, H_{Ar}), 7.05-7.09 (m, 4H, H_{Ar}), 7.56 (dd, 2H, *J* = 8.1, 7.2 Hz, H_{Ar}), 7.77 (d, 2H, *J* = 8.1 Hz, H_{Ar}), 7.80 (s, 2H, H_{Ar}), 7.85 (d, 2H, *J* = 7.2 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298 K, $CDCl_3$): δ = -115.8; ^{13}C-NMR (75 MHz, 298 K, $CDCl_3$): δ = 114.9 ($J_{C,F}$ = 21.2 Hz), 120.3, 123.6, 126.9, 128.1, 131.5 ($J_{C,F}$ = 7.9 Hz) (CH_{Ar}), 129.5, 132.6, 136.5, 137.7, 138.8, 138.9, 161.8 ($J_{C,F}$ = 244.5 Hz) (C_{Ar}); IR (Neat): $\tilde{\nu}$ = 3051, 2920, 2850, 1771 (w), 1715, 1596, 1506, 1463, 1418, 1344, 1296, 1223, 1155, 1093, 1010, 822 (m), 771 (s), 725, 674, 607, 531 (m) cm^{-1}; GC-MS (EI, 70 eV): *m/z* (%) = 391 (30), 390 (M^+, 100), 389 (24), 388 (21), 386 (10), 370 (18), 368 (20), 185 (23), 184 (25); elmental analysis: calcd. (%) for $C_{28}H_{16}F_2$ (290.423): C = 86.14, H = 4.13; Found: C = 85.74, H = 4.06.

8,9-Di(pyridin-2-yl)fluoranthene (4l):



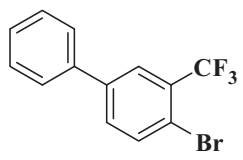
Starting with 1,2-dibromoacenaphthylene ***2*** (310 mg, 1.0 mmol) and 2-pyridyl styrene ***3l***, ***4l*** was isolated as a dark brownish heavy oil (199 mg, 56 %). ^{1}H-NMR (300 MHz, 298 K, $CDCl_3$): δ = 6.96 (d, 2H, *J* = 7.8 Hz, $H_{Pyridyl}$), 7.08 (m, 2H, $H_{pyridyl}$), 7.38 (dt, 2H, *J* = 5.9, 7.8 Hz, $H_{pyridyl}$), 7.57 (dd, 2H, *J* = 6.9, 8.2 Hz, H_{Ar}), 7.79 (d, 2H, *J* = 8.2 Hz, H_{Ar}), 7.92 (d, 2H, *J* = 6.9 Hz, H_{Ar}) 8.17 (s, 2H, H_{Ar}), 8.61 (d, 2H, *J* = 5.9 Hz, $H_{pyridyl}$); ^{13}C-NMR (75 MHz, 299 K, $CDCl_3$): δ = 120.8, 121.6 (CH_{Ar}), 123.6, 125.5 ($CH_{Pyridyl}$), 127.0, 128.1 (CH_{Ar}), 130.0, 133.2 (C_{Ar}), 135.6 ($CH_{Pyridyl}$), 136.5, 138.9, 139.7 (C_{Ar}), 149.5 ($CH_{Pyridyl}$), 159.4(C_{Ar}); IR (Neat): $\tilde{\nu}$ = 3044 (w), 2920, 2850 (m), 1770 (w), 1712 (m), 1584, 1454, 1428 (s), 1392, 1330, 1249, 1147, 1091, 1034, 989, 889 (m), 821, 772, 745 (s), 701, 617, 537 (m) cm^{-1}; EI-MS (EI, 70 eV): *m/z* (%) = 357 (10), 356 (M^+, 47), 355 (100), 354 (12), 353 (9), 328 (14), 327 (5), 178 (19), 164 (4); HRMS (ESI-TOF): calcd. for $C_{26}H_{17}N_2$ $[M+H]^+$: 357.138600; Found: 357.139700.

7.5 Synthesis of Trifluoromethyl-Substituted Di- and Terphenyls by Site-Selective Suzuki Miyaura Reactions of 1,4-Dibromo-2-trifluoromethyl-benzene.

Typical procedure for the synthesis of **4-bromo-3-(trifluoromethyl)biphenyls** ***(27a-o):***

The reaction was carried out in a pressure tube. To a dioxane suspension (5 mL) of the **1,4-dibromo-2-(trifluoromethyl)benzene** ***(25)***, **$Pd(PPh_3)_4$** (3-5 mol%) and of the **arylboronic acid** ***(26)*** was added an aqueous solution of K_2CO_3 (2 M, 1-2 mL). The mixture was heated at the indicated temperature (70 °C) under Argon atmosphere for the indicated period of time (8 h). The solution was cooled to 20 °C, poured into H_2O and CH_2Cl_2 (5 mL each), and the organic and the aqueous layers were separated. The later was extracted with CH_2Cl_2 (3 x 15 mL). The combined organic layers were washed with H_2O (3 x 10 mL), dried (Na_2SO_4), and concentrated in vacuo. The residue was purified by chromatography (flash silica gel, heptanes/EtOAc) to give **4-Bromo-3-(trifluoromethyl)biphenyls** ***(27a-o)*** (79-94%).

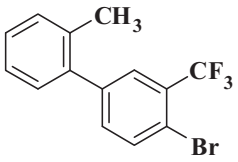
4-Bromo-3-(trifluoromethyl)biphenyl (27a):



Starting from ***25*** (150 mg, 0.5 mmol), and ***26a*** (61 mg, 0.5 mmol), ***27a*** was obtained as a colorless oil (123 mg, 82 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 7.30-7.38 (m, 3H, H_{Ar}), 7.44-7.49 (m, 3H, H_{Ar}), 7.66 (d, 1H, *J* =

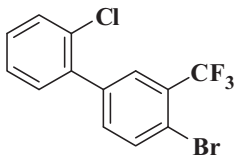
8.2 Hz, H_{Ar}), 7.78 (d, 1H, J = 8.2 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.5; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 118.7 ($J_{C,F}$ = 8.2 Hz, C_{Ar}), 122.9 ($J_{C,F}$ = 271 Hz, CF_3), 126.4 ($J_{C,F}$ = 5.5 Hz), 126.9, 128.4, 129.1 (CH_{Ar}), 130.4 ($J_{C,F}$ = 32.3 Hz, C_{Ar}), 131.3. 135.3 (CH_{Ar}), 138.6, 140.7 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3064, 3033, 1603 (w), 1470, 1401 (m), 1322 (s), 1251 (m), 1171, 1125, 1100, 1017 (s), 964, 898, 830 (m), 757, 694 (s), 617 (w), 545 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) 300 (M^+, ^{79}Br, 100), 221 (13), 219 (7), 201 (29), 170 (5), 152 (25), 151 (10), 150 (9), 111 (8); HRMS (EI): calcd. for $C_{13}H_8{}^{79}BrF_3$ $[M]^+$: 299.975600; Found: 299.975571.

4'-Bromo-2-methyl-3'-(trifluoromethyl)biphenyl (27b):



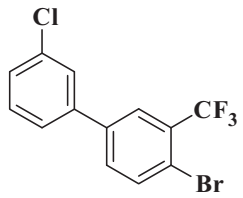
Starting from ***25*** (150 mg, 0.5 mmol), and ***26b*** (68 mg, 0.5 mmol), ***27b*** was obtained as a colorless oil (137 mg, 87 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 2.17 (s, 3H, CH_3), 7.09-7.26 (m, 5H, H_{Ar}), 7.56 (d, 1H, J = 2.1 Hz, H_{Ar}), 7.66 (d, 1H, J = 8.1 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.5; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 20.3 (CH_3), 118.4 ($J_{C,F}$ = 1.9 Hz, C_{Ar}), 122.9 ($J_{C,F}$ = 272 Hz, CF_3), 126.1, 128.2, 128.5 ($J_{C,F}$ = 5.3 Hz), 129.5 (CH_{Ar}), 129.9 ($J_{C,F}$ = 31.0 Hz, C_{Ar}), 130.6, 133.6, 134,7 (CH_{Ar}), 135.1, 139.2, 141.4 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3062, 3021, 2955, 1599 (w), 1470, 1399 (m), 1321 (s), 1248 (m), 1171, 1126, 1097, 1019 (s), 965, 906, 833 (m), 757, 724 (s), 659, 592, 555 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) 314 (M^+, ^{79}Br, 99), 235 (17), 234 (11), 233 (10), 215 (22), 214 (12), 166 (68), 165 (70), 115 (8), 107 (8), 91 (7). HRMS (EI): calcd. for $C_{14}H_{10}{}^{79}BrF_3$ $[M]^+$: 313.991250; Found: 313.991255.

4'-Bromo-2-chloro-3'-(trifluoromethyl)biphenyl(27c):



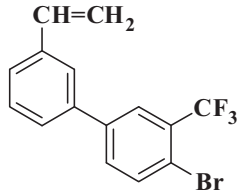
Starting from ***25*** (150 mg, 0.5 mmol), and ***26c*** (78 mg, 0.5 mmol), ***27c*** was obtained as a yellowish heavy oil (141 mg, 84 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 7.22-7.27 (m, 3H, H_{Ar}), 7.37-7.42 (m, 2H, H_{Ar}), 7.67-7.69 (m, 2H, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.5; ^{13}C-NMR (63 MHz, 300K, $CDCl_3$): δ = 119.3 ($J_{C,F}$ = 1.9 Hz, C_{Ar}), 122.8 ($J_{C,F}$ = 274 Hz, CF_3), 127.2, 128.8 ($J_{C,F}$ = 5.4 Hz), 129.4 ($J_{C,F}$ = 31.7 Hz C_{Ar}), 129.5, 130.2, 131.0 (CH_{Ar}), 132.3 (C_{Ar}), 133.9, 134.6 (CH_{Ar}), 137.9, 138.7 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3060, 1924, 1604, 1561 (w), 1464, 1389 (m), 1324 (s), 1283, 1242, 1173 (m), 1125 (s), 1074 (m), 1017 (s), 964 (w), 906, 831 (m), 753 (s), 696, 657 (m), 590 (w), 550 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) 334 (M^+, ^{79}Br+^{35}Cl, 76), 255 (9), 220 (23), 219 (15), 201 (8), 186 (8), 170 (7), 150 (9), 110 (7); HRMS (EI): calcd. for $C_{13}H_7{}^{79}Br{}^{35}ClF_3$ $[M]^+$: 333.936630; Found: 333.936584.

4-Bromo-3'-chloro-3-(trifluoromethyl)biphenyl (27d):



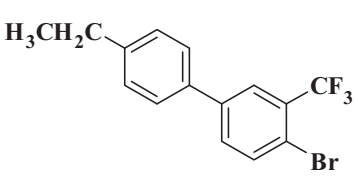
Starting from ***25*** (150 mg, 0.5 mmol), and ***26d*** (78 mg, 0.5 mmol), ***27d*** was obtained as a colorless oil (144 mg, 86 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 7.28-7.33 (m, 3H, H_{Ar}), 7.43-7.46 (m, 2H, H_{Ar}), 7.67 (d, 1H, J = 8.3 Hz, H_{Ar}), 7.75 (d, 1H, J = 2.2 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.64; ^{13}C-NMR (75 MHz, 300K, $CDCl_3$): δ = 119.5 ($J_{C,F}$ = 1.8 Hz, C_{Ar}), 122.8 ($J_{C,F}$ = 272 Hz, CF_3), 125.1, 126.3 ($J_{C,F}$ = 5.4 Hz), 127.1, 128.4, 130.4 (CH_{Ar}), 130.6 ($J_{C,F}$ = 31.1 Hz, C_{Ar}), 131.2 (CH_{Ar}), 135.1 (C_{Ar}), 135.5 (CH_{Ar}), 139.2, 140.4 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3060, 1924, 1807, 1604, 1562 (w), 1464, 1398 (m), 1324 (s), 1242 (m), 1173, 1126 (s), 1074 (m), 1017 (s), 964, 906, 831 (m), 753 (s), 696, 657 (m), 590 (w), 550 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 334 (M^+, ^{79}Br+^{35}Cl, 78), 255 (10), 220 (22), 219 (14), 201 (7), 186 (8), 170 (5), 169 (6), 150 (5); HRMS (EI): calcd. for $C_{13}H_7{}^{79}Br^{35}ClF_3$ $[M]^+$: 333.936630; Found: 333.936717.

4-Bromo-3-(trifluoromethyl)-3'-vinylbiphenyl (27e):



Starting from ***25*** (150 mg, 0.5 mmol), and ***26e*** (74 mg, 0.5 mmol), ***27e*** was obtained as a colorless oil (137 mg, 84 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 5.21 (d, 1H, J = 10.8 Hz, =CH_2), 5.71 (d, 1H, J = 17.5 Hz, =CH_2), 6.65 (dd, 1H, J = 17.5, 10.8 Hz, =CH), 7.28-7.33 (m, 3H, H_{Ar}), 7.42-7.46 (m, 2H, H_{Ar}), 7.63 (d, 1H, J = 8.2 Hz, H_{Ar}), 7.76 (d, 1H, J = 2.1 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.51; ^{13}C-NMR (63 MHz, 300K, $CDCl_3$): δ = 114.8 (=CH_2), 118.8 ($J_{C,F}$ = 1.8 Hz, C_{Ar}), 122.9 ($J_{C,F}$ = 274 Hz, CF_3), 124.9, 126.0, 126.3, 126.4 ($J_{C,F}$ = 5.4 Hz), 129.3 (CH_{Ar}), 130.4 ($J_{C,F}$ = 31.2 Hz, C_{Ar}), 131.3, 135.3 (CH_{Ar}), 136.0 (=CH), 138.4, 138.9, 140.5 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3045, 2927, 1892 (w), 1600, 1513, 1473, 1424 (m), 1324 (s), 1266, 1236, 1173 (m), 1126 (s), 1020 (m), 903, 843 (m), 819 (s), 722, 659, 570 (m) cm^{-1} GC-MS (EI, 70 eV): m/z (%) 326 (M^+, ^{79}Br, 100), 247 (8), 246 (12), 227 (6), 225 (5), 178 (25), 176 (11), 152 (6), 152 (6); HRMS (EI): calcd. for $C_{15}H_{10}{}^{79}BrF_3$ $[M]^+$: 325.991250; Found: 325.990805.

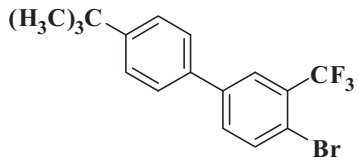
4-Bromo-4'-ethyl-3-(trifluoromethyl)biphenyl (27f):



Starting from ***25*** (150 mg, 0.5 mmol), and ***26f*** (75 mg, 0.5 mmol), ***27f*** was obtained as a colorless oil (143 mg, 87 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 1.18 (t, 3H, J = 7.5 Hz, CH_3), 7.60 (q, 2H,

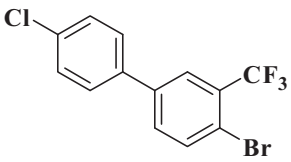
J = 7.5 Hz, CH_2), 7.20 (d, 2H, J = 8.3 Hz, H_{Ar}), 7.39 (d, 2H, J = 8.3 Hz, H_{Ar}), 7.46 (dd, 1H, J = 8.2, 2.2 Hz, H_{Ar}), 7.64 (d, 1H, J = 8.3 Hz, H_{Ar}), 7.78 (d, 1H, J = 2.2 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.55; ^{13}C-NMR (63 MHz, 300K, $CDCl_3$): δ = 15.5 (CH_3), 28.5 (CH_2), 118.3 ($J_{C,F}$ = 1.8 Hz, C_{Ar}), 122.9 ($J_{C,F}$ = 273 Hz, CF_3), 126.2 ($J_{C,F}$ = 5.4 Hz), 126.8, 128.6 (CH_{Ar}), 130.3 ($J_{C,F}$ = 31.5 Hz, C_{Ar}), 131.3, 135.2 (CH_{Ar}), 136.0, 140.6, 144.7 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3027, 2965, 2873, 1602 (w), 1472, 1423 (m), 1323 (s), 1251 (m), 1171 (m), 1128, 1100 (s), 1014 (m), 964 (w), 902 (m), 817 (s), 773, 716, 660 (m), 612 (w), 548 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 328 (M^+, ^{79}Br, 72), 316 (15), 315 (100), 314 (16), 313 (99), 249 (8), 234 (13), 233 (9), 183 (8), 178 (6), 165 (28); HRMS (EI): calcd. for $C_{15}H_{12}{}^{79}BrF_3$ $[M]^+$: 328.006900; Found: 328.006104.

4-Bromo-4'-tert-butyl-3-(trifluoromethyl)biphenyl (27g):



Starting from ***25*** (150 mg, 0.5 mmol), and ***26g*** (90 mg, 0.5 mmol), ***27g*** was obtained as a yellowish heavy oil (158 mg, 88 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 1.28 (s, 9H, $((CH_3)_3)$), 7.42 (s, 4H, H_{Ar}), 7.50 (dd, 1H, J = 2.1, 8.3 Hz, H_{Ar}), 7.67 (d, 1H, J = 8.2 Hz, H_{Ar}), 7.80 (d, 1H, J = 2.1 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.61; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 31.2 ($(CH_3)_3$), 34.6 ($C(CH_3)_3$), 118.3 ($J_{C,F}$ = 1.9 Hz, C_{Ar}), 123.0 ($J_{C,F}$ = 272 Hz, CF_3), 126.1, 126.3 ($J_{C,F}$ = 5.4 Hz), 126.6 (CH_{Ar}), 130.4 ($J_{C,F}$ = 31.7 Hz, C_{Ar}), 131.1, 135.2 (CH_{Ar}), 135.7, 140.6, 151.6 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3034, 2961, 2868, 1601 (w), 1473, 1418 (m), 1325 (s), 1251, 1172 (m), 1129, 1100 (s), 1021 (m), 962 (w), 902 (m), 818 (s), 743, 697, 659 (m), 603 (w), 566 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 356 (M^+, ^{79}Br, 28), 344 (18), 343 (98), 342 (19), 341 (100), 315 (20), 313 (20), 262 (10), 233 (7), 222 (8), 165 (7), 157 (8), 156 (9); HRMS (EI): calcd. for $C_{17}H_{16}{}^{79}BrF_3$ $[M]^+$: 356.038200; Found: 356.038994.

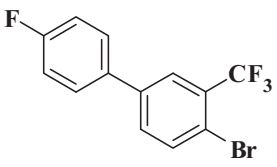
4-Bromo-4'-chloro-3-(trifluoromethyl)biphenyl (27h):



Starting from ***25*** (150 mg, 0.5 mmol), and ***26h*** (78 mg, 0.5 mmol), ***27h*** was obtained as a white solid (139 mg, 83 %), mp = 50-52 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 7.35-7.42 (m, 4H, H_{Ar}), 7.46 (dd, 1H, J = 2.0, 8.1 Hz, H_{Ar}), 7.69 (d, 1H, J = 8.1 Hz, H_{Ar}), 7.76 (d, 1H, J = 2.0 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.61; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 119.1 ($J_{C,F}$ = 1.9 Hz, C_{Ar}), 122.8 ($J_{C,F}$ = 272 Hz, CF_3), 126.2 ($J_{C,F}$ = 5.4 Hz), 128.2, 129.3 (CH_{Ar}), 130.6 ($J_{C,F}$ = 31.0 Hz, C_{Ar}), 131.1 (CH_{Ar}), 134.6 (C_{Ar}) 135.5 (CH_{Ar}), 137.1, 139.5 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3037, 2926, 1899, 1596 (w), 1470, 1417 (m), 1324 (s), 1248, 1171 (m), 1127, 1094, 1010 (s), 961 (w), 903 (m), 812 (s), 746,

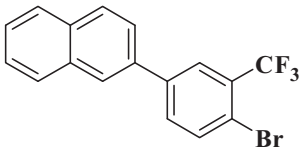
695, 658 (m), 597 (w), 544 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 334 (M^+, $^{79}Br+^{35}Cl$, 76), 255 (11), 235 (8), 220 (18), 219 (16), 201 (8), 186 (9), 151 (6), 150 (5), 128 (7); HRMS (EI): calcd. for $C_{13}H_7{}^{79}Br^{35}ClF_3$ $[M]^+$: 333.936630; Found: 333.936462.

4-Bromo-4'-fluoro-3-(trifluoromethyl)biphenyl (27i):



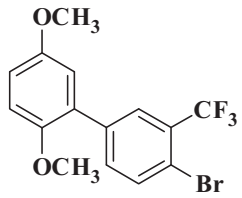
Starting from ***25*** (150 mg, 0.5 mmol), and ***26i*** (70 mg, 0.5 mmol), ***27i*** was obtained as a yellowish heavy oil (128 mg, 80 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 7.04-7.10 (m, 2H, H_{Ar}), 7.41-7.46 (m, 2H, H_{Ar}), 7.67 (d, 1H, J = 8.2 Hz, H_{Ar}), 7.75 (d, 1H, J = 2.2 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.61, -113.65; ^{13}C-NMR (63 MHz, 298K, $CDCl_3$): δ = 116.1 ($J_{C,F}$ = 21.7 Hz, CH_{Ar}), 118.7 ($J_{C,F}$ = 1.8 Hz, C_{Ar}), 122.8 ($J_{C,F}$ = 274 Hz, CF_3), 126.2 ($J_{C,F}$ = 5.4 Hz), 128.2 ($J_{C,F}$ = 8.2 Hz) (CH_{Ar}), 130.6 ($J_{C,F}$ = 31.2 Hz, C_{Ar}), 131.1 (CH_{Ar}), 134.8 ($J_{C,F}$ = 3.3 Hz, C_{Ar}) 135.4 (CH_{Ar}), 139.7, 163.0 ($J_{C,F}$ = 248.9 Hz) (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3045, 1892 (w), 1600, 1513 (m), 1473 (s), 1424, 1391 (m), 1325 (s), 1249 (m), 1173, 1099 (s), 1020 (m), 961 (w), 903 (m), 819 (s), 722, 659 (m), 612 (w), 570 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 318 (M^+, ^{79}Br, 100), 299 (10), 239 (17), 237 (8), 219 (35), 188 (6), 170 (28), 169 (9), 120 (8); HRMS (EI): calcd. for $C_{13}H_7{}^{79}BrF_4$ $[M]^+$: 317.966180; Found: 317.966583.

2-(4-Bromo-3-(trifluoromethyl)phenyl)naphthalene (27j):



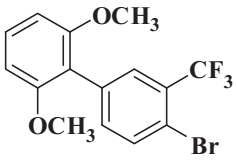
Starting from ***25*** (150 mg, 0.5 mmol), and ***26j*** (86 mg, 0.5 mmol), ***27j*** was obtained as a white crystalline solid (139 mg, 79 %), mp = 206-208 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 7.40-7.44 (m, 2H, H_{Ar}), 7.54-7.59 (m, 2H, H_{Ar}), 7.67 (d, 1H, J = 8.3 Hz, H_{Ar}), 7.75-7.88 (m, 5H, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.4; ^{13}C-NMR (63 MHz, 298K, $CDCl_3$): δ = 118.8 ($J_{C,F}$ =1.8 Hz, C_{Ar}), 123.0 ($J_{C,F}$ = 274 Hz, CF_3), 124.7, 126.0, 126.5 ($J_{C,F}$ = 5.4 Hz), 126.6, 126.7, 127.7, 128.2, 128.9 (CH_{Ar}), 130.3, 130.8 (C_{Ar}), 131.5 (CH_{Ar}), 132.2 ($J_{C,F}$ = 34.4 Hz, C_{Ar}) 135.4 (CH_{Ar}), 135.9, 140.6 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3048, 2916, 1586 (w), 1479, 1433, 1382, 1301 (m), 1230 (w), 1158, 1091, 1017 (m), 969, 885 (w), 814 (m), 743, 689 (s), 617 (m), 541 (w) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 350 (M^+, ^{79}Br, 100), 271 (13), 270 (9), 269 (9), 251 (12), 220 (5), 202 (27), 200 (9), 176 (6); HRMS (EI): calcd. for $C_{17}H_{10}{}^{79}BrF_3$ $[M]^+$: 349.991250; Found: 349.990657.

4'-Bromo-2,5-dimethoxy-3'-(trifluoromethyl)biphenyl (27k):



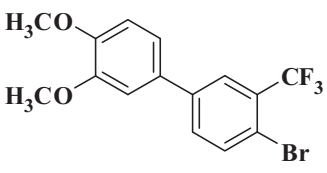
Starting from ***25*** (150 mg, 0.5 mmol), and ***26k*** (91 mg, 0.5 mmol), ***27k*** was obtained as a slight yellowish dense oil (166 mg, 92 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 3.65, 3.69 (s, 6H, 2 OCH_3), 6.76-6.79 (m, 3H, H_{Ar}), 7.43 (dd, 1H, J = 1.9, 8.2 Hz, H_{Ar}), 7.61 (d, 1H, J = 8.2 Hz, H_{Ar}), 7.75 (d, 1H, J = 1.9 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.48; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 55.7, 55.8 (OCH_3), 112.7, 114.0, 116.4 (CH_{Ar}), 118.4 ($J_{C,F}$ = 1.8 Hz, C_{Ar}), 123.0 ($J_{C,F}$ = 274 Hz, CF_3), 128.8 ($J_{C,F}$ = 5.4 Hz, CH_{Ar}), 128.9, 129.7 ($J_{C,F}$ = 31.0 Hz, C_{Ar}), 133.9, 134.5 (CH_{Ar}), 137.9, 150.5, 153.9 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3067, 2995, 2937, 2832, 1586 (w), 1515, 1474, 1401, 1327, 1286 (m), 1245, 1166, 1097, 1015 (s), 969, 910, 855 (m), 812 (s), 762, 671, 620, 582, 531 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 360 (M^+, ^{79}Br, 99), 347 (12), 345 (12), 267 (15), 266 (95), 252 (5), 251 (33), 223 (18), 218 (6), 207 (5), 206 (6), 195 (12), 188 (8), 175 (8), 169 (11); HRMS (EI): calcd. for $C_{15}H_{12}O_2{}^{79}BrF_3$ $[M]^+$: 359.996730; Found: 359.996175.

4'-Bromo-2,6-dimethoxy-3'-(trifluoromethyl)biphenyl (27l):



Starting from ***25*** (150 mg, 0.5 mmol), and ***26l*** (91 mg, 0.5 mmol), ***27l*** was obtained as a colorless dense oil (157 mg, 87 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 3.65 (s, 6H, 2 OCH_3), 6.39-6.43 (m, 1H, H_{Ar}), 7.20-7.30 (m, 4H, H_{Ar}), 7.62 (d, 1H, J = 8.2 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.35; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 55.8 (2 OCH_3), 104.1 (CH_{Ar}), 117.9 ($J_{C,F}$ = 1.7 Hz, C_{Ar}), 123.2 ($J_{C,F}$ = 275.1 Hz, CF_3), 128.9, 129.5 ($J_{C,F}$ = 31.2 Hz, C_{Ar}), 129.7 ($J_{C,F}$ = 5.3 Hz), 129.8, 134.1, 135.7 (CH_{Ar}), 137.8, 157.9 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3065, 2999, 2935, 2830, 1587 (w), 1517, 1475, 1402, 1325, 1288 (m), 1245, 1165, 1098, 1015 (s), 971, 912, 855 (m), 811 (s), 762, 671, 615, 581, 530 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 360 (M^+, ^{79}Br, 100), 343 (5), 341 (5), 267 (5), 266 (30), 265 (5), 252 (5), 251 (24), 250 (7), 237 (6), 236 (9), 223 (16), 207 (8), 206 (7), 195 (10), 175 (7), 169 (8); HRMS (EI): calcd. for $C_{15}H_{12}O_2{}^{79}BrF_3$ $[M]^+$: 359.996730; Found: 359.995736.

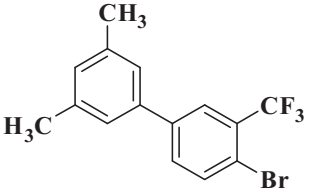
4-Bromo-3',4'-dimethoxy-3-(trifluoromethyl)biphenyl (27m):



Starting from ***25*** (150 mg, 0.5 mmol), and ***26m*** (91 mg, 0.5 mmol), ***27m*** was obtained as a colorless heavy oil (170 mg, 94 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 3.85, 3.87 (s, 6H, 2 OCH_3), 6.87 (d, 1H, J = 8.2 Hz, H_{Ar}), 6.96 (d, 1H, J = 2.1 Hz, H_{Ar}), 7.02 (dd, 1H, J = 2.1, 8.2 Hz, H_{Ar}), 7.45 (dd, 1H, J = 2.2, 8.3 Hz, H_{Ar}), 7.64 (d, 1H, J = 8.3 Hz, H_{Ar}), 7.75 (d, 1H, J = 2.2

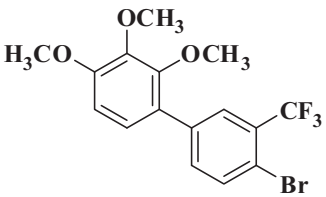
Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.48; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 55.7, 55.8 (OCH_3), 112.7, 114.0, 116.4 (CH_{Ar}), 118.4 ($J_{C,F}$ = 1.8 Hz, C_{Ar}), 123.0 ($J_{C,F}$ = 274 Hz, CF_3), 128.8 ($J_{C,F}$ = 5.4 Hz, CH_{Ar}), 128.9, 129.7 ($J_{C,F}$ = 31.0 Hz, C_{Ar}), 133.9, 134.5 (CH_{Ar}), 137.9, 150.5, 153.9 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3066, 2998, 2937, 2833, 1588 (w), 1516, 1474, 1400, 1328, 1289 (m), 1244, 1166, 1099, 1016 (s), 970, 911, 856 (m), 810 (s), 761, 670, 619, 583, 532 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 360 (M^+, ^{79}Br, 100), 347 (14), 345 (14), 319 (16), 317 (17), 281 (7), 239 (8), 238 (56), 236 (8), 220 (11), 219 (5), 207 (8), 195 (15), 175 (6), 169 (8); HRMS (EI): calcd. for $C_{15}H_{12}O_2{}^{79}BrF_3$ $[M]^+$: 359.996730; Found: 359.996658.

4-Bromo-3',5'-dimethyl-3-(trifluoromethyl)biphenyl (27n):



Starting from ***25*** (150 mg, 0.5 mmol), and ***26n*** (75 mg, 0.5 mmol), ***27n*** was obtained as a colorless heavy oil (137 mg, 83 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 2.30 (s, 6H, $2CH_3$), 6.98 (s, 1H, H_{Ar}), 7.09 (s, 1H, H_{Ar}), 7.49 (dd, 1H, J = 1.9, 8.3 Hz, H_{Ar}), 7.66 (d, 1H, J = 8.3 Hz, H_{Ar}), 7.78 (d, 1H, J = 1.9 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.53; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 21.4 (CH_3), 118.4 ($J_{C,F}$ = 1.9 Hz, C_{Ar}), 122.9 ($J_{C,F}$ = 273 Hz, CF_3), 124.8, 126.4 ($J_{C,F}$ = 5.4 Hz, CH_{Ar}), 129.9 (CH_{Ar}), 130.9 ($J_{C,F}$ = 31.0 Hz, C_{Ar}), 131.3, 135.1 (CH_{Ar}), 138.6, 138.7, 138.9, 140.9 (C_{Ar}); IR (neat, cm^{-1}): $\tilde{\nu}$ = 3022 (w), 2921 (m), 2853 (w), 1604 (m), 1568 (w), 1468, 1391, 1334 (m), 1293 (s), 1251, 1207 (m), 1170 (m), 1128 (s), 1100, 1021 (m), 962, 892 (m), 825 (s), 760, 726 (w), 699, 659 (m), 597, 543 (w) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 328 (M^+, ^{79}Br, 100), 315 (19), 313 (19), 249 (11), 234 (17), 233 (12), 214 (5), 184 (5), 180 (12), 179 (9), 178 (9), 165 (25), 152 (5); HRMS (EI): calcd. for $C_{15}H_{12}{}^{79}BrF_3$ $[M]^+$: 328.006900; Found: 328.006512.

4'-Bromo-2,3,4-trimethoxy-3'-(trifluoromethyl)biphenyl (27o):



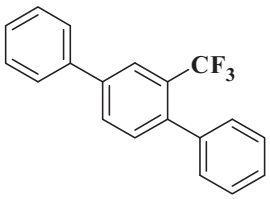
Starting from ***25*** (150 mg, 0.5 mmol), and ***26o*** (106 mg, 0.5 mmol), ***27o*** was obtained as a colorless heavy oil (160 mg, 82 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 3.63, 3.82, 3.84 (s, 9H, 3 OCH_3), 6.67 (d, 1H, J = 8.7 Hz, H_{Ar}), 6.93 (d, 1H, J = 8.7 Hz, H_{Ar}), 7.45 (dd, 1H, J = 8.3, 2.1 Hz, H_{Ar}), 7.63 (d, 1H, J = 8.3 Hz, H_{Ar}), 7.75 (d, 1H, J = 2.1 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.51; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 56.0. 61.0, 61.1 (OCH_3), 107.7 (CH_{Ar}), 118.0 ($J_{C,F}$ = 1.9 Hz, C_{Ar}), 123.0 ($J_{C,F}$ = 272 Hz, CF_3), 124.4 (CH_{Ar}), 125.9 (C_{Ar}), 128.4 ($J_{C,F}$ = 5.4 Hz, CH_{Ar}), 129.8 ($J_{C,F}$ = 30.7 Hz, C_{Ar}), 133.5, 134.6 (CH_{Ar}), 137.7, 142.7, 151.2, 154.0 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 2936, 2837 (w), 1595, 1498, 1462, 1417, 1325, 1278, 1209, 1171 (m), 1128,

1082, 1008 (s), 927, 903, 884, 834, 794, 723, 664 (m), 586 (w), 529 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 390 (M^+, ^{79}Br, 100), 377 (9), 375 (9), 334 (14), 332 (14), 296 (25), 281 (22), 263 (22), 261 (22), 236 (10), 195 (5), 182 (11); HRMS (EI): calcd. for $C_{16}H_{14}O_3{}^{79}BrF_3$ $[M]^+$: 390.007290; Found: 390.006929.

Typical procedure for the synthesis of 1,4-diaryl-3-(trifluoromethyl)benzene (28a-m):

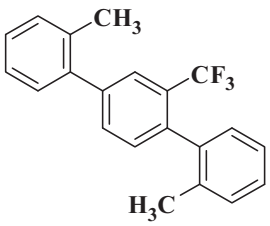
The reaction was carried out in a pressure tube. To a dioxane suspension (5 mL) of the **1,4-Dibromo-2-(trifluoromethyl)benzene *(25)***, **$Pd(PPh_3)_4$** (3-5 mol%) and of the **arylboronic acid *(26)*** was added an aqueous solution of K_2CO_3 (2 M, 1-2 mL). The mixture was heated at the indicated temperature (90 °C) under Argon atmosphere for the indicated period of time (8 h). The solution was cooled to 20 °C, poured into H_2O and CH_2Cl_2 (5 mL each), and the organic and the aqueous layers were separated. The later was extracted with CH_2Cl_2 (3 x 15 mL). The combined organic layers were washed with H_2O (3 x 10 mL), dried (Na_2SO_4), and concentrated in vacuo. The residue was purified by chromatography (flash silica gel, heptanes/EtOAc) to give **1,4-diaryl-3-(trifluoromethyl)benzene *(28a-m)*** (79-95%).

1,4-Diphenyl-3-(trifluoromethyl)-benzene (28a):



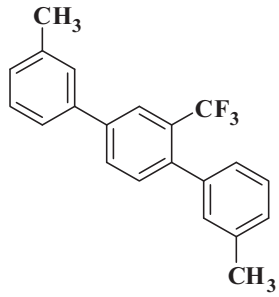
Starting from ***25*** (150 mg, 0.5 mmol), and ***26a*** (152 mg, 1.25 mmol), ***28a*** was obtained as a colorless heavy oil (127 mg, 85 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 7.26-7.58 (m, 11H, H_{Ar}), 7.68 (dd, 1H, J = 1.6, 7.9 Hz, H_{Ar}), 7.87 (d, 1H, J = 1.6 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -56.77; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 124.2 ($J_{C,F}$ = 273.1 Hz, CF_3), 124.8 ($J_{C,F}$ = 5.2 Hz), 127.1, 127.7, 128.8, 128.0, 128.9, 129.0 (CH_{Ar}), 129.3 ($J_{C,F}$ = 31.1 Hz, C_{Ar}), 129.7, 132.6 (CH_{Ar}), 139.5, 139.6, 140.2 ($J_{C,F}$ = 1.9 Hz), 140.5 (C_{Ar}); IR (neat, cm^{-1}): $\tilde{\nu}$ = 3346 (br.), 2973, 1581 (w), 1451, 1403, 1320, 1243, 1172 (m), 1124, 1071, 1044 (s), 1006, 977, 903, 879, 857, 837 (m), 761, 691 (s), 665, 597, 530 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 299 (49, M+1), 298 (M^+, 100), 278 (7), 277 (16), 259 (7), 257 (12), 229 (5), 228 (15), 227 (8), 226 (13), 202 (8), 201 (14), 149 (5); HRMS (EI): calcd. for $C_{19}H_{13}F_3$ $[M]^+$: 298.096390; Found: 298.096115.

2-Trifluoromethyl-1,4-bis(2-methylphenyl)-benzene (28b):



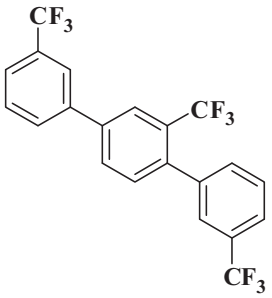
Starting from ***25*** (150 mg, 0.5 mmol), and ***26b*** (170 mg, 1.25 mmol), ***28b*** was obtained as a colorless heavy oil (139 mg, 85 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 2.02, 2.52 (s, 6H, 2 CH_3), 7.13-7.24 (m, 9H, H_{Ar}), 7.44 (m, 1H, H_{Ar}), 7.64 (d, 1H, J = 1.8 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -59.05; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 20.1, 20.4 (CH_3), 124.0 ($J_{C,F}$ = 270 Hz, CF_3), 124.8, 126.7 ($J_{C,F}$ = 5.1 Hz), 127.9 (CH_{Ar}), 128.5 ($J_{C,F}$ = 30.9 Hz, C_{Ar}), 129.5, 129.6, 129.7, 130.6, 131.4, 131.9 (CH_{Ar}), 135.3, 136.1, 138.7, 139.0, 140.2 ($J_{C,F}$ = 1.9 Hz), 141.1 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3021, 2924 (w), 1477, 1404 (m), 1321 (s), 1288, 1244 (m), 1167, 1117 (s), 1068, 1026, 1006 (m), 943 (w), 907, 846 (m), 753, 723 (s), 663, 583, 543 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 327 (24), 326 (M^+, 100), 311 (17), 285 (15), 271 (13), 270 (19), 258 (15), 257 (65), 242 (38), 241 (33), 239 (29), 215 (14), 165 (25); HRMS (EI): calcd. for $C_{21}H_{17}F_3$ $[M]^+$: 326.127690; Found: 326.127240.

2-Trifluoromethyl-1,4-bis(3-methylphenyl)-benzene (28c):



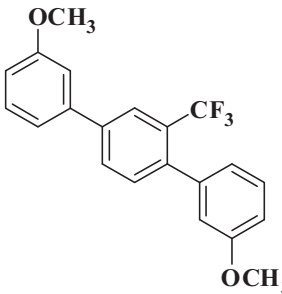
Starting from ***25*** (150 mg, 0.5 mmol), and ***26p*** (170 mg, 1.25 mmol), ***28c*** was obtained as a yellowish heavy oil (140 mg, 86 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 2.32, 2.36 (s, 6H, 2 CH_3), 7.07-7.36 (m, 9H, H_{Ar}), 7.66 (dd, 1H, J = 7.9, 1.6 Hz, H_{Ar}), 7.86 (d, 1H, J = 1.6 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -56.72; ^{13}C-NMR (75 MHz, 299K, $CDCl_3$): δ = 21.4, 21.5 (CH_3), 123.2 (CH_{Ar}), 123.6 ($J_{C,F}$ = 275 Hz, CF_3), 123.7 ($J_{C,F}$ = 5.4 Hz), 125.0, 126.6, 126.8, 127.3, 127.7, 127.9, 128.2, 128.6 ($J_{C,F}$ = 1.6 Hz) (CH_{Ar}), 131.5 ($J_{C,F}$ = 29.7 Hz, C_{Ar}), 131.7 (CH_{Ar}), 136.3, 137.6, 138.4, 138.5, 139.1 ($J_{C,F}$ = 1.8 Hz), 139.4 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3030, 2921 (w), 1605, 1477 (m), 1393 (w), 1325, 1273, 1244, 1163 (m), 1118 (s), 1073, 1054, 1033 (m), 971 (w), 894, 840 (m), 779, 700 (s), 665, 609 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 327 (23), 326 (M^+, 100), 305 (17), 291 (35), 271 (23), 270 (49), 257 (37), 242 (49), 241 (56), 239 (42), 215 (24), 165 (31), 163 (46); HRMS (EI): calcd. for $C_{21}H_{17}F_3$ $[M]^+$: 326.127690; Found: 326.127298.

2-Trifluoromethyl-1,4-bis(3-trifluoromethylphenyl)-benzene (28d):



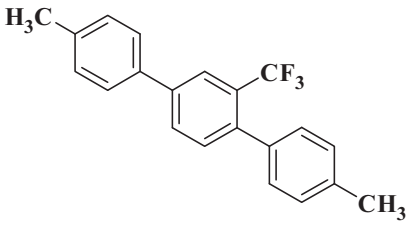
Starting from ***25*** (150 mg, 0.5 mmol), and ***26q*** (237 mg, 1.25 mmol), ***28d*** was obtained as a colorless heavy oil (178 mg, 82 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 7.37 (d, 1H, J = 5.3 Hz, H_{Ar}), 7.48 (m, 2H, H_{Ar}), 7.55-7.62 (m, 4H, H_{Ar}), 7.72-7.75 (m, 2H, H_{Ar}), 7.80 (s, 1H, H_{Ar}), 7.90 (d, J = 1.0 Hz, H_{Ar}); ^{19}F-NMR (283 MHz, 300K, $CDCl_3$): δ = -62.65, -56.91; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 123.9 ($J_{C,F}$ = 274.5 Hz, CF_3), 124.2 ($J_{C,F}$ = 275.2 Hz, CF_3), 123.9 ($J_{C,F}$ = 4.4 Hz), 124.7 ($J_{C,F}$ = 4.5 Hz), 125.1 ($J_{C,F}$ = 5.4 Hz), 125.8 ($J_{C,F}$ = 1.9 Hz), (CH_{Ar}), 129.3 ($J_{C,F}$ = 29.6 Hz, C_{Ar}), 129.6, 130.0 (CH_{Ar}), 130.0 ($J_{C,F}$ = 19.2 Hz, C_{Ar}), 130.5 (CH_{Ar}), 131.5 ($J_{C,F}$ = 19.4 Hz, C_{Ar}), 132.2, 132.6, 132.7 (CH_{Ar}), 139.2, 139.8, 139.9, 140.0 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3074, 3043 (w), 1481, 1431, 1398, 1332, 1313, 1245, 1164 (m), 1115, 1068, 1044 (s), 1001, 896, 845 (m), 799 (s), 759, 699, 653, 593, 561 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 435 (23), 434 (M^+, 100), 416 (12), 415 (27), 413 (15), 395 (23), 364 (13), 346 (24), 345 (47), 325 (19), 296 (25), 275 (14), 269 (24), 219 (18), 201 (16); HRMS (EI): calcd. for $C_{21}H_{11}F_9$ $[M]^+$: 434.071160; Found: 434.070626.

2-Trifluoromethyl-1,4-bis(3-methoxyphenyl)-benzene (28e):



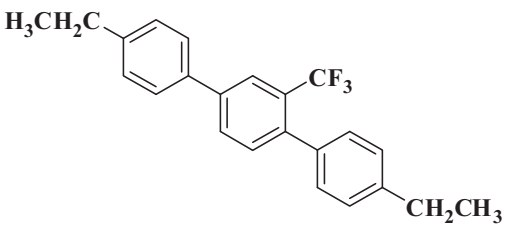
Starting from ***25*** (150 mg, 0.5 mmol), and ***26r*** (190 mg, 1.25 mmol), ***28e*** was obtained as a heavy oil (159 mg, 89 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 3.76, 3.81 (s, 6H, 2 OCH_3), 6.84-6.89 (m, 4H, H_{Ar}), 7.06-7.31 (m, 5H, H_{Ar}), 7.66-7.69 (dd, 1H, J = 8.0, 1.6 Hz, H_{Ar}), 7.86 (d, 1H, J = 1.6 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -56.84; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 55.2, 55.3 (OCH_3), 112.9, 113.3, 113.5, 114.7, 119.6, 121.5 (CH_{Ar}), 123.1 ($J_{C,F}$ = 273 Hz, CF_3), 124.8 ($J_{C,F}$ = 5.3 Hz, CH_{Ar}), 128.7 ($J_{C,F}$ = 30.3 Hz, C_{Ar}), 128.8, 130.0, 132.4 (CH_{Ar}), 14.0, 140.4 ($J_{C,F}$ = 1.9 Hz), 140.8, 140.9, 158.9, 160.1 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3032, 2919 (w), 1603, 1477 (m), 1392 (w), 1324, 1272, 1243, 1161 (m), 1116 (s), 1073, 1055, 1034 (m), 972 (w), 894, 842 (m), 779, 702 (s), 664, 607 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 359 (33), 358 (M^+, 100), 339 (27), 328 (39), 315 (53), 285 (21), 272 (17), 271 (14), 265 (15), 251 (42), 245 (24), 233 (23), 202 (26), 179 (52); HRMS (EI): calcd. for $C_{21}H_{17}O_2F_3$ $[M]^+$: 358.117520; Found: 358.117099.

2-Trifluoromethyl-1,4-bis(4-methylphenyl)-benzene (28f):



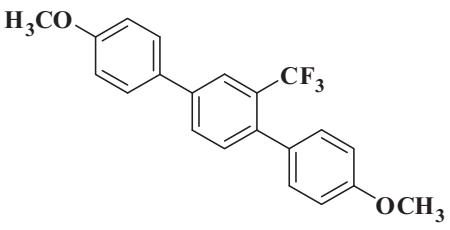
Starting from ***25*** (150 mg, 0.5 mmol), and ***26s*** (170 mg, 1.25 mmol), ***28f*** was obtained as a heavy oil (139 mg, 85 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 2.34 (s, 6H, 2 CH_3), 7.12-7.30 (m, 7H, H_{Ar}), 7.46 (d, 2H, J = 8.1 Hz, H_{Ar}), 7.65 (dd, 1H, J = 7.8, 1.5 Hz, H_{Ar}), 7.67 (d, 1H, J = 1.5 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -56.78; ^{13}C-NMR (63 MHz, 300K, $CDCl_3$): δ = 21.1, 21.2 (CH_3), 124.2 ($J_{C,F}$ = 275 Hz, CF_3), 124.5 ($J_{C,F}$ = 5.4 Hz), 126.9, 128.5 (CH_{Ar}), 128.7 ($J_{C,F}$ = 29.7 Hz, C_{Ar}), 128.8, 129.5, 129.7, 132.7 (CH_{Ar}), 136.6, 136.7, 137.3, 137.8, 139.9, 140.2 ($J_{C,F}$ = 1.9 Hz) (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3024, 2964, 1913, 1613 (w), 1487, 1423, 1323, 1265 (m), 1168, 1109 (s), 1068, 1004, 966, 902 (m), 811 (s), 757, 719, 666, 587 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 327 (23), 326 (M^+, 100), 305 (28), 291 (35), 271 (28), 270 (47), 257 (61), 256 (25), 242 (49), 241 (56), 239 (42), 215 (24), 207 (31), 200 (55), 165 (39), 163 (46), 152 (41), 135 (63), 121 (60), 119 (82), 105 (71), 91 (84), 69 (86); HRMS (EI): calcd. for $C_{21}H_{17}F_3$ $[M]^+$: 326.127690; Found: 326.127367.

2-Trifluoromethyl-1,4-bis(4-ethylphenyl)-benzene (28g):



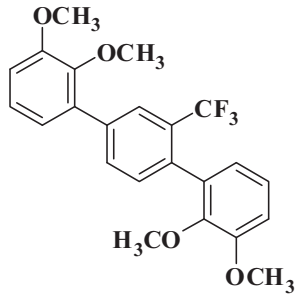
Starting from ***25*** (150 mg, 0.5 mmol), and ***26f*** (187 mg, 1.25 mmol), ***28g*** was obtained as a white heavy oil (154 mg, 87 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 1.20 (t, 6H, J = 7.6 Hz, CH_3), 2.61 (q, 4H, J = 7.6 Hz, CH_2), 7.13-7.29 (m, 7H, H_{Ar}), 7.46 (d, 2H, J = 8.2 Hz, H_{Ar}), 7.64 (dd, 1H, J = 7.8, 1.6 Hz, H_{Ar}), 7.85 (d, 1H, J = 1.6 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -56.72; ^{13}C-NMR (63 MHz, 300K, $CDCl_3$): δ = 15.4 (CH_3), 28.6 (CH_2), 124.2 ($J_{C,F}$ = 275 Hz, CF_3), 124.5 ($J_{C,F}$ = 5.4 Hz), 127.0, 127.3, 128.5, 128.9 ($J_{C,F}$ = 1.6 Hz), (CH_{Ar}), 129.0 ($J_{C,F}$ = 31.2 Hz, C_{Ar}), 129.5, 132.7 (CH_{Ar}), 136.9, 137.0, 139.9 ($J_{C,F}$ = 1.8 Hz), 140.2, 143.6, 144.2 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3024, 2964, 1905, 1796, 1613 (w), 1487, 1426 (m), 1323 (s), 1264 (m), 1166, 1114 (s), 1069, 1005 (m), 964 (w), 903 (m), 821 (s), 718, 667, 588 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 355 (25), 354 (M^+, 100), 340 (18), 339 (78), 324 (13), 270 (14), 252 (11), 241 (9), 239 (22), 169 (14), 162 (32); HRMS (EI): calcd. for $C_{23}H_{21}F_3$ $[M]^+$: 354.195640; Found: 354.195231.

2-Trifluoromethyl-1,4-bis(4-methoxyphenyl)-benzene (28h):



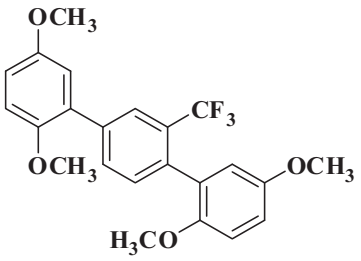
Starting from ***25*** (150 mg, 0.5 mmol), and ***26t*** (190 mg, 1.25 mmol), ***28h*** was obtained as a heavy oil (167 mg, 93 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 3.77, 3.78 (s, 6H, 2 OCH_3), 6.86 (d, 2H, J = 8.7 Hz, H_{Ar}), 6.93 (d, 2H, J = 8.7 Hz, H_{Ar}), 7.18-7.27 (m, 3H, H_{Ar}), 7.48 (d, 2H, J = 8.8 Hz, H_{Ar}), 7.62 (dd, 1H, J = 8.8, 1.6 Hz, H_{Ar}), 7.82 (d, 1H, J = 1.6 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -56.83; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 55.2, 55.4 (OCH_3), 113.3, 114.5, 124.2 ($J_{C,F}$ = 4.5 Hz) (CH_{Ar}) 124.3 ($J_{C,F}$ = 275 Hz, CF_3), 128.1, 129.2, 130.1 ($J_{C,F}$ = 1.4 Hz), (CH_{Ar}), 130.8 ($J_{C,F}$ = 30.9 Hz, C_{Ar}), 132.0 (CH_{Ar}), 132.8, 139.2, 139.3, 139.8 ($J_{C,F}$ = 1.9 Hz), 159.1, 159.7 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3028, 2922 (w), 1605, 1475 (m), 1395 (w), 1321, 1270, 1241, 1165 (m), 1118 (s), 1074, 1050, 1032 (m), 972 (w), 895, 839 (m), 778, 705 (s), 663, 607 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 359 (22), 358 (M^+, 100), 344 (12), 243 (32), 315 (14), 300 (14), 271 (17), 251 (41), 207 (15), 202 (22), 179 (49), 157 (28); HRMS (EI): calcd. for $C_{21}H_{17}O_2F_3$ $[M]^+$: 358.117520; Found: 358.116616.

2-Trifluoromethyl-1,4-bis(2,3-dimethoxyphenyl)-benzene (28i):



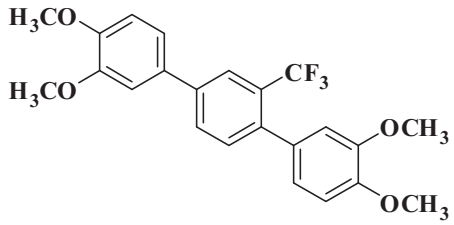
Starting from ***25*** (150 mg, 0.5 mmol), and ***26u*** (227 mg, 1.25 mmol), ***28i*** was obtained as a colorless heavy oil (182 mg, 87 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 3.55, 3.60, 3.84, 3.85 (s, 12H, 4 OCH_3), 6.79-7.10 (m, 6H, H_{Ar}), 7.29 (d, 1H, J = 7.9 Hz, H_{Ar}), 7.66 (dd, 1H, J = 7.9, 1.4 Hz, H_{Ar}), 7.87 (d, 1H, J = 1.4 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 299K, $CDCl_3$): δ = -57.9; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 55.8, 55.9, 60.5, 60.7 (OCH_3), 112.2, 112.3, 122.4, 122.9 (CH_{Ar}), 123.8 ($J_{C,F}$ = 275.1 Hz, CF_3), 124.3, 126.8 ($J_{C,F}$ = 5.4 Hz) (CH_{Ar}), 128.6 ($J_{C,F}$ = 29.4 Hz, C_{Ar}), 131.6, 132.0 (CH_{Ar}), 133.7, 134.2, 135.8, 135.9, 137.5, 146.6, 152.5, 153.2 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3075, 2935, 2835, 1679 (w), 1579 (m), 1511 (w), 1465 (s), 1402, 1328, 1300 (m), 1260 (s), 1166 (m), 1119 (s), 1060 (m), 1001 (s), 907, 841, 786, 744, 674, 592, 541 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 419 (27), 418 (M^+, 100), 388 (13), 369 (5), 368 (43), 363 (14), 353 (17), 252 (29), 325 (15), 304 (24), 209 (32); HRMS (EI): calcd. for $C_{23}H_{21}O_4F_3$ $[M]^+$: 418.138650; Found: 418.137837.

2-Trifluoromethyl-1,4-bis(2,5-dimethoxyphenyl)-benzene (28j):



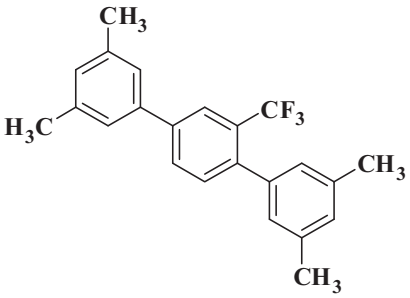
Starting from ***25*** (150 mg, 0.5 mmol), and ***26k*** (227 mg, 1.25 mmol), ***28j*** was obtained as a slight yellowish dense oil (165 mg, 79 %). ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 3.61, 3.68, 3.70, 3.72 (s, 12H, 4 OCH_3), 6.72-6.88 (m, 6H, H_{Ar}), 7.23 (d, 1H, J = 7.9 Hz, H_{Ar}), 7.64 (d, 1H, J = 7.9 Hz, H_{Ar}), 7.64 (dd, 1H, J = 7.9, 1.3 Hz, H_{Ar}), 7.82 (d, 1H, J = 1.3 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -58.81; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 55.7, 55.8, 56.1, 56.2 (OCH_3), 111.7, 112.6, 113.8, 113.9, 116.6, 116.8 ($J_{C,F}$ = 1.3 Hz), 117.2 (CH_{Ar}), 124.2 ($J_{C,F}$ = 272.5 Hz, CF_3), 127.1 ($J_{C,F}$ = 5.4 Hz, CH_{Ar}), 128.8 ($J_{C,F}$ = 29.5 Hz), 129.4, 129.8 (C_{Ar}), 131.8, 132.1 (CH_{Ar}), 135.9 ($J_{C,F}$ = 1.8 Hz), 137.7, 150.7, 151.1, 152.9, 153.9 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 2934, 2835 (w), 1593 (m), 1551 (w), 1480, 1413, 1321, 1289, 1209, 1163 (m), 1105, 1077, 1001 (s), 925, 868, 792, 725, 697, 654 (m), 573 (w) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 419 (25), 418 (M^+, 100), 388 (18), 369 (7), 368 (46), 363 (17), 353 (37), 352 (45), 325 (28), 297 (13), 209 (31), 194 (20); HRMS (EI): calcd. for $C_{23}H_{21}O_4F_3$ $[M]^+$: 418.138650; Found: 418.139359.

2-Trifluoromethyl-1,4-bis(3,4-dimethoxyphenyl)-benzene (28k):



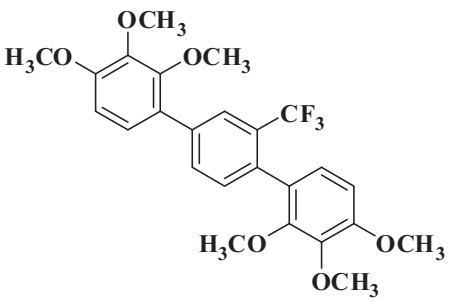
Starting from ***25*** (150 mg, 0.5 mmol), and ***26m*** (227 mg, 1.25 mmol), ***28k*** was obtained as a yellowish crystalline solid (198 mg, 95 %), mp = 110-112 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 3.80, 3.85, 3.86, 3.89 (s, 12H, 4 OCH_3), 6.84-7.12 (m, 6H, H_{Ar}), 7.32 (d, 1H, J = 7.9 Hz, H_{Ar}), 7.65 (dd, 1H, J = 7.9, 1.8 Hz, H_{Ar}), 7.81 (d, 1H, J = 1.8 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -56.78; ^{13}C-NMR (63 MHz, 300K, $CDCl_3$): δ = 55.8, 55.9, 56.1, 56.2 (OCH_3), 110.2, 110.5, 111.6, 112.5 ($J_{C,F}$ = 1.6 Hz), 119.5, 121.3 (CH_{Ar}), 124.2 ($J_{C,F}$ = 275.2 Hz, CF_3), 124.4 ($J_{C,F}$ = 5.3 Hz, CH_{Ar}), 128.8 ($J_{C,F}$ = 29.5 Hz, C_{Ar}), 129.4 (CH_{Ar}), 132.1, 132.4 (C_{Ar}), 132.7 (CH_{Ar}), 139.4 ($J_{C,F}$ = 1.8 Hz), 140.1, 148.1, 148.9, 149.2, 149.4 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 2935, 2836 (w), 1596 (m), 1555 (w), 1482, 1413, 1322, 1285, 1205, 1160 (m), 1107, 1074, 1002 (s), 923, 865, 792, 726, 693, 651 (m), 571 (w) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 419 (24), 418 (M^+, 100), 403 (25), 375 (30), 360 (48), 335 (31), 324 (23), 249 (19), 220 (15), 209 (49); HRMS (EI): calcd. for $C_{23}H_{21}O_4F_3$ $[M]^+$: 418.138650; Found: 418.138754.

2-Trifluoromethyl-1,4-bis(3,5-dimethylphenyl)-benzene (28l):



Starting from ***25*** (150 mg, 0.5 mmol), and ***26n*** (187 mg, 1.25 mmol), ***28l*** was obtained as a white crystalline solid (154 mg, 87 %), mp = 108-109 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 2.41, 2.43, 2.45, 2.46 (s, 12H, $4CH_3$), 7.03 (s, 2H, H_{Ar}), 7.08-7.10 (m, 2H, H_{Ar}), 7.28-7.30 (m, 2H, H_{Ar}), 7.41 (d, 1H, J = 7.9 Hz, H_{Ar}), 7.77 (dd, 1H, J = 7.9, 1.8 Hz, H_{Ar}), 7.97 (d, 1H, J = 1.8 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -56.70; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 21.3, 21.4 (CH_3), 124.2 ($J_{C,F}$ = 274 Hz, CF_3), 124.7 ($J_{C,F}$ = 5.4 Hz), 125.0 (CH_{Ar}), 125.1 (C_{Ar}), 126.8 ($J_{C,F}$ = 1.5 Hz, CH_{Ar}), 128.6 ($J_{C,F}$ = 29.5 Hz, C_{Ar}), 129.2, 129.6, 132.5 (CH_{Ar}), 137.2, 138.6, 139.5, 139.6, 140.2, 140.3, 140.5 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3020, 2916 (w), 1601, 1505, 1454, 1376, 1335 (m), 1293 (s), 1249 (m), 1199 (w), 1124 (s), 1088, 1048, 996 (m), 946 (w), 900 (m), 836 (s), 761, 701, 651, 580 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 355 (40), 354 (M^+, 100), 339 (15), 319 (32), 283 (22), 270 (44), 269 (30), 255 (39), 253 (41), 252 (36), 239 (33), 215 (19), 177 (39), 169 (24), 162 (48); HRMS (EI): calcd. for $C_{23}H_{21}F_3$ $[M]^+$: 354.158990; Found: 354.158570.

2-Trifluoromethyl-1,4-bis(2,3,4-trimethoxyphenyl)-benzene (28m):

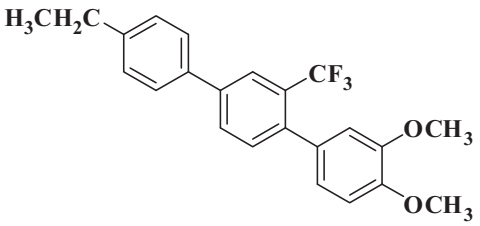


Starting from ***25*** (150 mg, 0.5 mmol), and ***26o*** (265 mg, 1.25 mmol), ***28m*** was obtained as a white crystalline solid (218 mg, 91 %), mp = 85-87 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 3.73, 3.79 (s, 6H, 2 OCH_3), 3.94 (s, 9H, 3 OCH_3), 3.97 (s, 3H, OCH_3), 6.72 (d, 1H, J = 8.6 Hz, H_{Ar}), 6.81 (d, 1H, J = 8.6 Hz, H_{Ar}), 6.95 (d, 1H, J = 8.5 Hz, H_{Ar}), 7.13 (d, 1H, J = 8.5 Hz, H_{Ar}), 7.36 (d, 1H, J = 7.9 Hz, H_{Ar}), 7.71 (dd, 1H, J = 7.9, 1.7 Hz, H_{Ar}), 7.91 (d, 1H, J = 1.7 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -56.78; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 55.9, 56.0, 60.8, 60.9, 61.0, 61.1 (OCH_3), 106.3, 107.6 (CH_{Ar}), 124.2 ($J_{C,F}$ = 273 Hz, CF_3), 124.7, 125.0 ($J_{C,F}$ = 1.4 Hz) (CH_{Ar}), 126.1 (C_{Ar}), 126.6 ($J_{C,F}$ = 5.3 Hz, CH_{Ar}), 126.9, 128.9 ($J_{C,F}$ = 29.2 Hz, C_{Ar}), 131.5, 132.4 (CH_{Ar}), 135.3 ($J_{C,F}$ = 2.0 Hz), 137.4, 141.9, 142.6, 151.4, 151.5, 153.6, 151.7 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 2936, 2837 (w), 1597 (m), 1555 (w), 1481, 1412, 1325, 1287, 1208, 1165 (m), 1108, 1078, 1003 (s), 920, 866, 793, 727, 695, 655 (m), 570 (w) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 479 (29), 478 (M^+, 100), 448 (28), 428 (25), 420 (43), 413 (36), 412 (45), 397 (14), 349 (35), 239 (52), 224 (22), 167 (25), 146 (24), 110 (9); HRMS (EI): calcd. for $C_{25}H_{25}O_6F_3$ $[M]^+$: 478.159770; Found: 478.159508.

Typical procedure for the synthesis of 1,4-diaryl-3-(trifluoromethyl)benzene (29a-d):

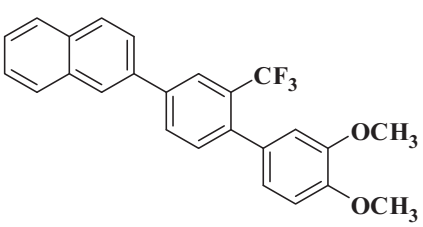
The reaction was carried out in a pressure tube. To a dioxane suspension (5 mL) of the **1,4-dibromo-2-(trifluoromethyl)benzene** ***(25)***, **$Pd(PPh_3)_4$** (3-5 mol%) and of the **arylboronic acid** ***(26)*** was added an aqueous solution of K_2CO_3 (2 M, 1-2 mL). The mixture was heated at the indicated temperature (90 °C) under Argon atmosphere for the indicated period of time (8 h). The solution was cooled to 20 °C, poured into H_2O and CH_2Cl_2 (5 mL each), and the organic and the aqueous layers were separated. The later was extracted with CH_2Cl_2 (3 x 15 mL). The combined organic layers were washed with H_2O (3 x 10 mL), dried (Na_2SO_4), and concentrated in vacuo. The residue was purified by chromatography (flash silica gel, heptanes/EtOAc) to give **1,4-diaryl-3-(trifluoromethyl)benzene** ***(29a-d)*** (80-88%).

1-(3',4'-Dimethoxy)-phenyl-4-(4''-ethyl)-phenyl-2-trifluoromethylbenzene (29a):



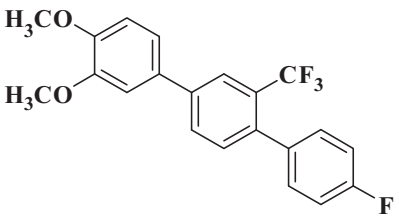
Starting from ***27f*** (82 mg, 0.25 mmol), and ***26m*** (45 mg, 0.25 mmol), ***29a*** was obtained as a yellowish crystalline solid (85 mg, 88 %), mp = 185-186 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 1.21 (t, 3H, J = 7.6 Hz, CH_3), 2.64 (q, 2H, J = 7.6 Hz, CH_2), 3.81, 3.85 (s, 6H, 2 OCH_3), 6.82-6.85 (m, 3H, H_{Ar}), 7.24 (d, 2H, J = 8.3 Hz, H_{Ar}), 7.33 (dd, 1H, J = 7.9 Hz, H_{Ar}), 7.48 (d, 2H, J = 8.3 Hz, H_{Ar}), 7.66 (dd, 1H, J = 7.9, 1.8 Hz, H_{Ar}), 7.85 (d, 1H, J = 1.8 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -56.81; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 15.5 (CH_3), 28.5 (CH_2), 55.9 (2 OCH_3), 110.5, 112.6, 121.4 (CH_{Ar}), 124.2 ($J_{C,F}$ = 278 Hz, CF_3), 124.6 ($J_{C,F}$ = 5.3 Hz), 127.0, 128.5 (CH_{Ar}), 128.6 ($J_{C,F}$ = 28.7 Hz, C_{Ar}), 129.5 (CH_{Ar}), 132.2 (C_{Ar}), 132.7 (CH_{Ar}) 136.8, 139.7, 140.3, 144.3. 148.1, 148.6 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3062, 2966, 2869, 1604, 1551 (w), 1488, 1454, 1409, 1322, 1248, 1216, 1164 (m), 1115 (s), 1071 (m), 1024 (s), 969 (m), 933 (w), 904, 868 (m), 817 (s), 764, 719, 646, 609, 541 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 387 (25), 386 (M^+, 100), 371 (31), 343 (25), 313 (39), 303 (25), 285 (22), 275 (30), 259 (41), 215 (16), 186 (49), 164 (13), 144 (29); HRMS (EI): calcd. for $C_{23}H_{21}O_2F_3$ $[M]^+$: 386.148820; Found: 386.148894.

1-(3',4'-Dimethoxy)-phenyl-4-naphthyl-2-trifluoromethylbenzene (29b):



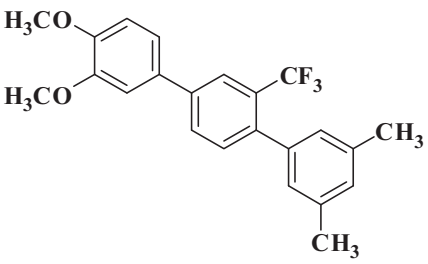
Starting from ***27j*** (88 mg, 0.25 mmol), and ***26m*** (45 mg, 0.25 mmol), ***29b*** was obtained as a yellowish crystalline solid (87 mg, 85 %), mp = 212-214 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 3.81, 3.84 (s, 6H, 2 OCH_3), 6.82-6.86 (m, 3H, H_{Ar}), 7.36-7.45 (m, 3H, H_{Ar}), 7.67 (dd, 1H, J = 8.5, 1.8 Hz, H_{Ar}), 7.77-7.87 (m, 4H, H_{Ar}), 8.00 (s, 2H, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -56.72; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 55.9, 56.0 (OCH_3), 110.4, 112.6, 121.4 (CH_{Ar}), 122.8 ($J_{C,F}$ = 275.2 Hz, CF_3), 125.0, 125.1, 126.0, 126.4, 126.6 (CH_{Ar}), 127.1, 127.3 (C_{Ar}), 127.7, 128.3 (CH_{Ar}), 128.5 ($J_{C,F}$ = 29.7 Hz, C_{Ar}), 128.8, 129.9 (CH_{Ar}), 132.1 (C_{Ar}), 132.9 (CH_{Ar}), 133.6, 136.7, 140.0, 140.2, 148.2, 148.7 (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3052, 2954, 2834, 1602 (w), 1495, 1462, 1407 (m), 1369 (w), 1314 (m), 1244, 1217, 1164, 1118 (s), 1071 (m), 1022 (s), 952, 886, 857 (m), 811, 748 (s), 719, 644, 607, 553 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 409 (27), 408 (M^+, 100), 393 (13), 365 (32), 350 (29), 326 (23), 325 (47), 322 (30), 305 (14), 297 (16), 296 (44), 253 (14), 252 (39), 204 (59), 163 (52), 162 (36); HRMS (EI): calcd. for $C_{25}H_{19}O_2F_3$ $[M]^+$: 408.133170; Found: 408.133547.

1-(4'-Fluoro)-phenyl-4-(3'',4''-dimethoxy)-phenyl-2-trifluoromethylbenzene (29c):



Starting from ***27m*** (90 mg, 0.25 mmol), and ***26i*** (35 mg, 0.25 mmol), ***29c*** was obtained as a yellowish crystalline solid (75 mg, 80 %) mp = 79-81 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 3.94, 4.02 (s, 6H, 2 OCH_3), 6.98-7.81 (m, 10H, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -56.82, -114.69; ^{13}C-NMR (63 MHz, 300K, $CDCl_3$): δ = 55.8, 56.0 (OCH_3), 110.2, 110.6, 114.7 ($J_{C,F}$ = 21.5 Hz), 119.6 (CH_{Ar}), 124.1 ($J_{C,F}$ = 274.5 Hz, CF_3), 124.5 ($J_{C,F}$ = 5.4 Hz) 128.7 ($J_{C,F}$ = 8.2 Hz (CH_{Ar}), 128.3, 129.3 ($J_{C,F}$ = 30.2 Hz) (C_{Ar}), 129.5 (CH_{Ar}), 130.7 (C_{Ar}), 132.6 (CH_{Ar}), 132.8, 140.6, 149.3, 149.4, 162.3 ($J_{C\text{-}F}$ = 247.2) (C_{Ar}); IR (neat): $\tilde{\nu}$ = 3063, 2969, 2845, 1602 (w), 1525, 1488, 1428, 1332, 1294 (m), 1244, 1171, 1109 (s), 1055, 1021 (m), 970, 925 (w), 837, 806 (s), 764, 724, 670, 648 (m), 595 (w), 537 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 377 (23), 376 (M^+, 100), 361 (23), 333 (30), 293 (39), 290 (20), 269 (14), 233 (20), 221 (24), 220 (46), 188 (44); HRMS (EI): calcd. for $C_{21}H_{16}O_2F_4$ $[M]^+$: 376.108090; Found: 376.107788.

1-(3',5'-Dimethyl)-phenyl-4-(3'',4''-dimethoxy)-phenyl-2-trifluoromethylbenzene (29d):



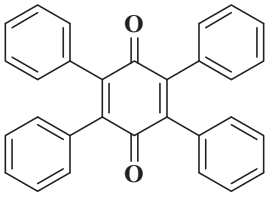
Starting from ***27m*** (90 mg, 0.25 mmol), and ***26n*** (38 mg, 0.25 mmol), ***29d*** was obtained as a yellowish crystalline solid (83 mg, 86 %), mp = 154-156 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 2.28 (s, 6H, $2CH_3$), 3.86, 3.90 (s, 6H, 2 OCH_3), 6.89-6.95 (m, 4H, H_{Ar}), 7.06 (d, 1H, J = 2.1 Hz, H_{Ar}), 7.12 (dd, 1H, J = 8.2, 2.1 Hz, H_{Ar}), 7.28 (d, 1H, J = 7.9 Hz, H_{Ar}), 7.63 (dd, 1H, J = 7.9, 1.8 Hz, H_{Ar}), 7.81 (d, 1H, J = 1.8 Hz, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -56.74; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 56.0. 61.0, 61.1 (OCH_3), 107.7 (CH_{Ar}), 118.0 ($J_{C,F}$ = 1.9 Hz, C_{Ar}), 123.0 ($J_{C,F}$ = 272 Hz, CF_3), 124.4 (CH_{Ar}), 125.9 (C_{Ar}), 128.4 ($J_{C,F}$ = 5.4 Hz, CH_{Ar}), 129.8 ($J_{C,F}$ = 30.7 Hz, C_{Ar}), 133.5, 134.6 (CH_{Ar}), 137.7, 142.7, 151.2, 154.0 (C_{Ar}); IR (neat): $\widetilde{\nu}$ = 3000, 2916, 2843 (w), 1600, 1520, 1465 (m), 1389 (w), 1331, 1293 (m), 1244, 1112, 1047 (s), 966, 899 (m), 837 (s), 763, 708, 658, 616, 574 (m) cm^{-1}; GC-MS (EI, 70 eV): m/z (%) 387 (36), 386 (M^+, 100), 371 (28), 367 (20), 343 (59), 303 (29), 285 (25), 283 (31), 259 (25), 239 (26), 216 (14), 215 (36), 193 (28), 185 (33), 164, (41); HRMS (EI): calcd. for $C_{23}H_{21}O_2F_3$ $[M]^+$: 386.148820; Found: 386.148991.

7.6 Synthesis of Tetraaryl-p-benzoquinones by Suzuki Cross-Coupling Reactions of Tetrabromo-p-benzo-quinone.

General procedure for the synthesis of tetraarylated-p-benzoquinones (31a-s):

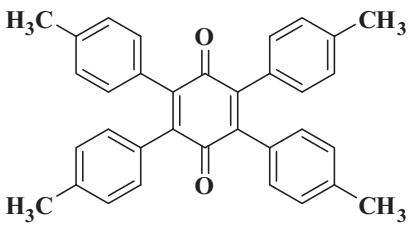
To a mixture of ***30*** (0.21 g, 0.5 mmol), ***26*** (2.0 mmol), palladium catalyst **[tetrakis(triphenylphosphine)]** in argon flushed pressure tube was added **THF** (5 mL) and aqueous **K_2CO_3** (2 mL, 2 M). The reaction mixture was refluxed for 12-hrs. The reaction mixture was allowed to cool down to room temperature and then dist. cold distilled water (8 mL) was added to it. Stirring for additional 15 minutes the mixture was extracted with dichloromethane (3 x 20 mL). The organic layer was washed with brine, dried over anhyd. Na_2SO_4, filtered and concentrated in vacuo which resulted in the formation of an inseparable 1:1 mixture of ***31*** and corresponding 2,3,5,6-tetraaryl-*p*-dihydrobenzoquinone. The mixture (***31*** and corresponding 2,3,5,6-tetraaryl-*p*-dihydrobenzoquinone) was treated with **DDQ** (0.85 mmol) in benzene (8.5 mL) was stirred at room temperature for 3 h. The reaction mixture was filtered, dried (Na_2SO_4) and concentrated in vacuo. The residue was purified by chromatography (silica gel, heptanes/EtOAc = 9:1) to get product (***31a-s***, 51-92%) .

2,3,5,6-Tetraphenylcyclohexa-2,5-diene-1,4-dione (31a):



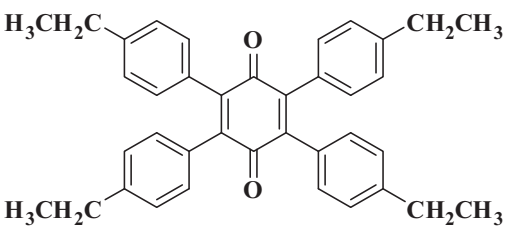
Starting from ***30*** (211 mg, 0.5 mmol), and ***26a*** (244 mg, 2.0 mmol), ***31a*** was obtained (144 mg, 70 %), mp = 304-306 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 7.02-7.16 (m, 16H, 4Ph); ^{13}C-NMR (62 MHz, 300K, $CDCl_3$): δ = 127.6, 128.2, 130.7 (CH_{Ar}), 132.8, 143.0 (C_{Ar}), 186.8 (C=O); IR (neat): $\tilde{\nu}$ = 3264, 3078 (w), 2919, 2850 (m), 1646 (s), 1593, 1441 (m), 1282, 1138 (s), 1054 (m), 997, 930, 853 783 (m), 691 (s), 549 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 414 (16, M^+), 413 (21), 412 (62), 384 (32), 356 (21), 207 (20), 178 (100), 176 (19), 153 (13), 151 (15); HRMS (ESI-TOF): calcd. for $C_{30}H_{21}O_2$ $[M+H]^+$: 413.153610; Found: 413.153220.

2,3,5,6-Tetrap-tolylcyclohexa-2,5-diene-1,4- dione (31b):



Starting from ***30*** (211 mg, 0.5 mmol), and ***26s*** (272 mg, 2.0 mmol), ***31b*** was obtained (175 mg, 75 %), mp = 262-264 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 2.21 (s, 12H, $4CH_3$), 6.91 (d, 8H, J = 8.4 Hz, H_{Ar}), 6.95 (d, 8H, ^{3}J = 8.4 Hz, H_{Ar}); ^{13}C-NMR (62 MHz, 298K, $CDCl_3$): δ = 21.3 (CH_3), 128.3 (CH_{Ar}), 130.0 (C_{Ar}), 130.7 (CH_{Ar}), 138.0, 142.6 (C_{Ar}), 187.1 (C=O); IR (neat): $\tilde{\nu}$ = 3079, 2920 (w), 1646, 1504 (m), 1404 (w), 1292 (s), 1214 (w), 1135 (s), 1058 (m), 907 (w), 802, 722 (s), 661 (m), 590 (w) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 471 (31), 470 (M^+, 100), 468 (15), 440 (14), 206 (21), 149 (29), 119 (45), 91 (14), 81 (15), 71 (19), 57 (23), 43 (35); HRMS (ESI-TOF): calcd. for $C_{34}H_{28}NaO_2$ $[M+Na]^+$: 491.198150; Found: 491.197850.

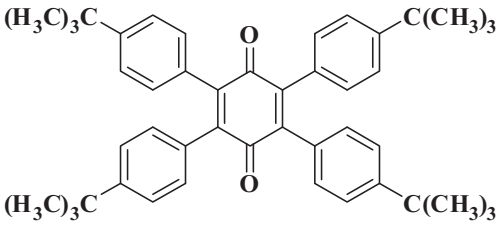
2,3,5,6-Tetrakis(4-ethylphenyl)cyclohexa-2,5-diene-1,4- dione (31c):



Starting from ***30*** (211 mg, 0.5 mmol), and ***26f*** (300 mg, 2.0 mmol), ***31c*** was obtained (210 mg, 80 %), mp = 271-273 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 1.12 (t, 12H, J = 7.2 Hz, $4CH_3$), 2.51 (q, 8H, J = 7.2 Hz, $4CH_2$), 6.96 (d, 8H, J = 8.3 Hz, $8H_{Ar}$), 7.04 (d, 8H, J = 8.3 Hz, $8H_{Ar}$); ^{13}C-NMR (62 MHz, 298K, $CDCl_3$): δ = 15.1 (CH_3), 28.5 (CH_2), 124.3 (CH_{Ar}), 130.3 (C_{Ar}), 130.9 (CH_{Ar}), 142.8, 144.2 (C_{Ar}), 180.7 (C=O); IR (neat, cm^{-1}): $\tilde{\nu}$ = 3082, 3027 (w), 2962,

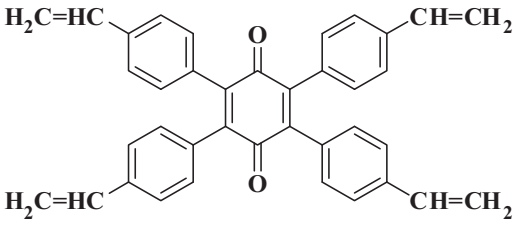
2868, 1651, 1607 (m), 1557 (w), 1503, 1409 (m), 1287 (s), 1184 (m), 1135 (s), 1062, 858 (m), 818 (s), 762, 687 (m), 568 (s) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 527 (38), 526 (M^+, 100), 524 (31), 496 (77), 468 (32), 439 (18), 410 (18), 363 (11), 234 (44), 219 (59), 204 (30), 175 (18), 29 (8); HRMS (ESI-TOF): calcd. for $C_{38}H_{36}NaO_2$ $[M+Na]^+$: 547.260750; Found: 547.260530.

2,3,5,6-Tetrakis(4-tert-butylphenyl)cyclohexa-2,5-diene-1,4- dione (31d):



Starting from ***30*** (211 mg, 0.5 mmol), and ***26g*** (356 mg, 2.0 mmol), ***31d*** was obtained (248 mg, 78 %), mp = 253-255 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 1.17 (s, 36H, $12CH_3$), 6.93 (d, 8H, *J* = 8.6 Hz, $8H_{Ar}$), 7.12 (d, 8H, *J* = 8.6 Hz, $8H_{Ar}$); ^{13}C-NMR (63 MHz, 298K, $CDCl_3$): δ = 31.1 (CH_3), 34.5 (C), 124.3 (CH_{Ar}), 130.1 (C_{Ar}), 130.7 (CH_{Ar}), 142.8, 151.1 (C_{Ar}), 187.2 (C=O); IR (neat): $\tilde{\nu}$ = 3085 (w), 2958, 1650 (m), 1582 (w), 1502, 1393, 1304, 1197 (m), 1100 (s), 1015 (m), 965 (w), 820 (s), 723, 643 (m), 562 (s) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 639 (49), 638 (M^+, 100), 608 (38), 304 (27), 129 (35), 111 (53), 97 (23), 85 (16), 83 (26), 71 (25), 57 (75), 43 (31); HRMS (ESI-TOF): calcd. for $C_{46}H_{53}O_2$ $[M+H]^+$: 637.404010; Found: 637.402780.

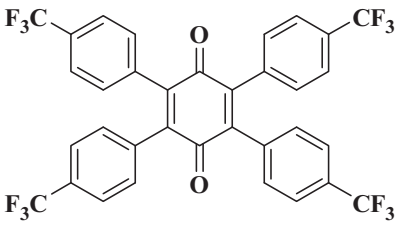
2,3,5,6-Tetrakis(4-vinylphenyl)cyclohexa-2,5-diene-1,4- dione (31e):



Starting from ***30*** (211 mg, 0.5 mmol), and ***26v*** (296 mg, 2.0 mmol), ***31e*** was obtained (145 mg, 56 %), mp = 275-277 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 5.17 (d, 4H, *J* = 10.5 Hz, $=CH_2$), 5.64 (d, 4H, *J* = 16.9 Hz, $=CH_2$), 6.55 (dd, 4H, *J* = 16.9, 10.5 Hz, =CH), 7.00 (d, 8H, *J* = 8.3 Hz, H_{Ar}), 7.19 (d, 8H, *J* = 8.3 Hz, H_{Ar}); ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 114.7 ($=CH_2$), 125.6, 131.1 (CH_{Ar}), 132.3 (C_{Ar}), 136.3 (=CH), 137.5, 142.5 (C_{Ar}), 186.6 (C=O); IR (neat): $\tilde{\nu}$ = 3270, 3088 (w), 2922 (m), 1648 (s), 1552 (w), 1503, 1402, 1286 (m), 1207 (w), 1135, 1057, 987, 907 (m), 826 (s), 756 (m), 695 (s), 644 (w), 526 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 519 (39), 518 (M^+, 100), 516 (12), 488 (24), 421 (15), 416 (17), 288 (8), 181 (11),

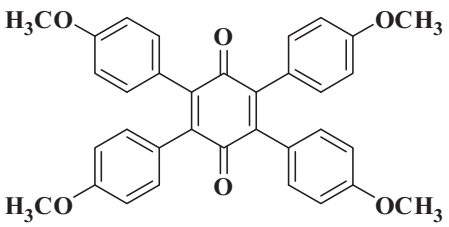
169 (19), 131 (19), 119 (14), 97 (17), 60 (15), 57 (29), 45 (20), 44 (54), 43 (55), 42 (11), 41 (22); HRMS (ESI-TOF): calcd. for $C_{38}H_{36}NaO_6$ $[M+Na]^+$: 611.240410; Found: 611.239870.

2,3,5,6-Tetrakis(4-(trifluoromethyl)phenyl)cyclohexa-2,5-diene-1,4- dione (31f):



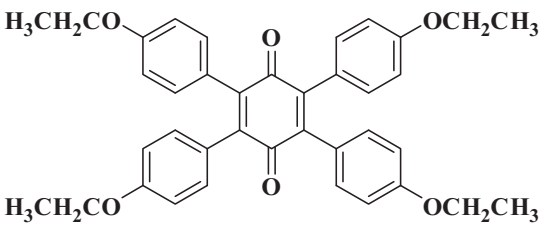
Starting from ***30*** (211 mg, 0.5 mmol), and ***26w*** (380 mg, 2.0 mmol), ***31f*** was obtained (175 mg, 51 %), mp = 196-198 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 7.14 (d, 8H, *J* = 8.0 Hz, $8H_{Ar}$), 7.45 (d, 8H, *J* = 8.0 Hz, $8H_{Ar}$); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -62.9; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 123.6 ($J_{C,F}$ = 272 Hz, CF_3), 125.0, 130.9 (CH_{Ar}), 131.1 ($J_{C,F}$ = 32 Hz, C_{Ar}), 135.4, 142.7 (C_{Ar}), 185.1 (C=O); IR (neat): $\tilde{\nu}$ = 3070, 2935 (w), 1656 (m), 1599, 1517 (w), 1408 (m), 1323 (s), 1286, 1160 (m), 1105, 1063 (s), 1016, 957 (m), 867 (w), 825 (m), 773, 734 (m), 667 (w), 598 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 687 (16), 686 (M^+, 43), 685 (100), 683 (21), 614 (18), 294 (12), 173 (14), 169 (27), 131 (17), 119 (22), 111 (15), 97 (38), 91 (15), 83 (56), 71 (68), 69 (85), 57 (71), 55 (48), 44 (45), 43 (86), 41 (74); HRMS (ESI-TOF): calcd. for $C_{34}H_{17}F_{12}O_2$ $[M+H]^+$: 685.102140; Found: 685.102990.

2,3,5,6-Tetrakis(4-methoxyphenyl)cyclohexa-2,5-diene-1,4- dione (31g):



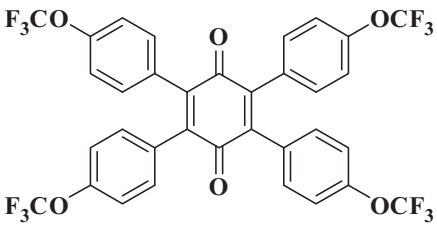
Starting from ***30*** (211 mg, 0.5 mmol), and ***26t*** (304 mg, 2.0 mmol), ***31g*** was obtained (245 mg, 92 %), mp = 205-207 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 3.69 (s, 12H, $4OCH_3$), 6.68 (d, 8H, *J* = 8.0 Hz, $8H_{Ar}$), 6.96 (d, 8H, *J* = 8.0 Hz, $8H_{Ar}$); ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 55.1 (OCH_3), 113.2 (CH_{Ar}), 125.4 (C_{Ar}), 132.4 (CH_{Ar}), 141.9, 159.4 (C_{Ar}), 187.4 (C=O); IR (neat): $\tilde{\nu}$ = 3259, 3011 (w), 2931, 2837 (m), 2539 (w), 1645 (m), 1601 (s), 1573, 1504, 1454 (m), 1244, 1173 (s), 1111 (m), 1023 (s), 934 (m), 807 (s), 734, 665, 597, 538 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 535 (31), 534 (M^+, 100), 504 (25), 383 (32), 267 (47), 239 (41), 223 (29), 195 (52), 165 (23), 163 (40), 152 (49), 135 (64), 121 (75), 43 (62); HRMS (ESI-TOF): calcd. for $C_{34}H_{28}NaO_6$ $[M+Na]^+$: 555.177810; Found: 555.177130.

2,3,5,6-Tetrakis(4-ethoxyphenyl)cyclohexa-2,5-diene-1,4- dione (31h):



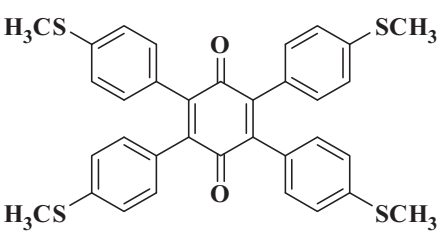
Starting from ***30*** (211 mg, 0.5 mmol), and ***26x*** (332 mg, 2.0 mmol), ***31h*** was obtained (262 mg, 89 %), mp = 178-180 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 1.30 (t, 12H, *J* = 6.9 Hz, CH_3), 3.91 (q, 8H, *J* = 6.9 Hz, OCH_2), 6.66 (d, 8H, *J* = 8.0 Hz, H_{Ar}), 6.94 (d, 8H, *J* = 8.0 Hz, H_{Ar}); ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 14.7 (CH_3), 63.3 (OCH_2), 113.7 (CH_{Ar}), 125.3 (C_{Ar}), 132.4 (CH_{Ar}), 141.9, 158.7 (C_{Ar}), 187.4 (C=O); IR (neat, cm^{-1}): $\tilde{\nu}$ = 3261 (w), 3039, 2874 (m), 2250 (w), 1643 (m), 1602, 1504 (s), 1389 (m), 1245 (s), 1173, 1114, 1043, 905, 819 (m), 727 (s), 635, 553 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 591 (36), 590 (M^+, 100), 576 (35), 411 (48), 383 (32), 337 (45), 239 (27), 209 (49), 181 (51), 149 (70), 121 (85), 58 (76); HRMS (ESI-TOF): calcd. for $C_{38}H_{36}NaO_6$ $[M+Na]^+$: 611.240410; Found: 611.239870.

2,3,5,6-Tetrakis(4-(trifluoromethoxy)phenyl)cyclohexa-2,5-diene-1,4- dione (31i):



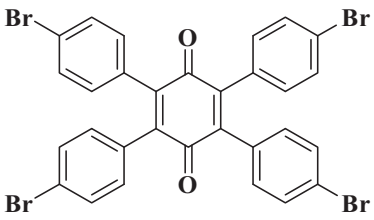
Starting from ***30*** (211 mg, 0.5 mmol), and ***26y*** (412 mg, 2.0 mmol), ***31i*** was obtained (303 mg, 81 %), mp = 159-161 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 7.04 (s, 16H, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -57.8; ^{13}C-NMR (62 MHz, 298K, $CDCl_3$): δ =120.1 (CH_{Ar}), 120.2 ($^{1}J_{C,F}$ = 271 Hz, OCF_3), 130.5 (C_{Ar}), 132.3 (CH_{Ar}), 142.3, 149.4 (C_{Ar}), 185.7 (C=O); IR (neat): $\tilde{\nu}$ = 3282, 3081 (w), 1655, 1606, 1498 (m), 1409 (w), 1302 (m), 1221, 1181, 1150, 1109 (s), 1057, 975, 913, 849, 802, 720, 654, 548 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 751 (35), 750 (M^+, 100), 720 (33), 346 (35), 152 (9), 97 (15), 95 (12), 85 (13), 84 (14), 83 (17), 81 (14), 77 (9), 71 (19), 69 (26), 67 (11), 57 (31), 55 (21), 45 (14), 43 (33), 41 (19); HRMS (EI): calcd. for $C_{34}H_{16}F_{12}O_6$ $[M]^+$: 748.074980; Found: 748.074596.

2,3,5,6-Tetrakis(4-(methylthio)phenyl)cyclohexa-2,5-diene-1,4- dione (31j):



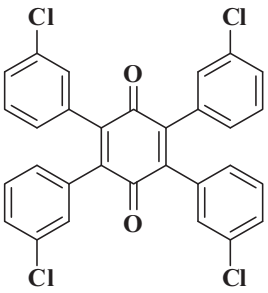
Starting from ***30*** (211 mg, 0.5 mmol), and ***26z*** (336 mg, 2.0 mmol), ***31j*** was obtained (257 mg, 86 %), mp = 217-219 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 2.37 (s, 12H, SCH_3), 6.93 (d, 8H, *J* = 8.6 Hz, H_{Ar}), 7.02 (d, 8H, *J* = 8.6 Hz, H_{Ar}); ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 15.1 (SCH_3), 125.1 (CH_{Ar}), 129.2 (C_{Ar}), 131.3 (CH_{Ar}), 139.5, 142.1 (C_{Ar}), 186.6 (C=O); IR (neat): $\widetilde{\nu}$ = 3056 (w), 2919 (m), 2852, 1899, 1816, 1765 (w), 1707, 1650 (m), 1589 (s), 1544 (w), 1487, 1422, 1359 (m), 1289 (s), 1219, 1166 (m), 1085 (s), 1012, 954, 877, 806 (m), 751, 694, 634, 528 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 599 (38), 598 (M^+, 100), 596 (17), 590 (51), 568 (40), 504 (12), 410 (7), 285 (9), 277 (15), 270 (40), 262 (18), 255 (25), 223 (12), 183 (19), 108 (10), 60 (17), 46 (13); HRMS (ESI-TOF): calcd. for $C_{34}H_{29}S_4O_2$ $[M+H]^+$: 597.104490; Found: 597.103550.

2,3,5,6-Tetrakis(4-bromophenyl)cyclohexa-2,5-diene-1,4- dione (31k):



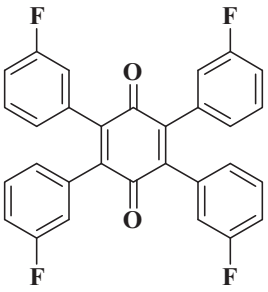
Starting from ***30*** (211 mg, 0.5 mmol), and ***26aa*** (402 mg, 2.0 mmol), ***31k*** was obtained (266 mg, 73 %), mp = 236-238 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 6.86 (t, 8H, *J* = 8.5 Hz, H_{Ar}), 7.32 (t, 8H, *J* = 8.5 Hz, H_{Ar}); ^{13}C-NMR (63 MHz, 298K, $CDCl_3$): δ = 123.3, 131.0 (C_{Ar}), 131.2, 132.3 (CH_{Ar}), 142.2 (C_{Ar}), 185.5 (C=O); IR (neat): $\widetilde{\nu}$ = 3272, 3052 (w), 2921 (m), 2851, 1898 (w), 1651, 1584 (m), 1537 (w), 1481, 1392 (m), 1344 (w), 1279 (m), 1181 (w), 1069, 1007, 906, 802, 772, 725 (m), 646 (w), 594, 532 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 730 (100, M^+, $^{81}Br_2$+$^{79}Br_2$), 726 (22, M-4, $^{79}Br_4$), 700 (11), 650 (10), 570 (15), 568 (14), 412 (20), 412 (14), 388 (18), 336 (23), 334 (14), 276 (16), 205 (39), 177 (15), 176 (63), 175 (19), 80 (10); HRMS (EI): calcd. for $C_{30}H_{16}O_2{}^{79}Br_3{}^{81}Br$ $[M]^+$: 725.785790; Found: 725.787594.

2,3,5,6-Tetrakis(3-chlorophenyl)cyclohexa-2,5-diene-1,4- dione (31l):



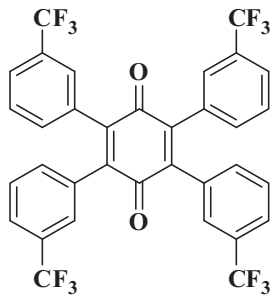
Starting from ***30*** (211 mg, 0.5 mmol), and ***26d*** (313 mg, 2.0 mmol), ***31l*** was obtained (206 mg, 75 %), mp = 230-232 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 6.10 (t, 4H, J = 7.9 Hz, H_{Ar}), 6.31-6.44 (m, 12H, H_{Ar}); ^{13}C-NMR (63 MHz, 298K, $CDCl_3$): δ = 128.7, 129.0, 129.2, 130.5 (CH_{Ar}), 133.6, 133.9, 142.3 (C_{Ar}), 185.4 (C=O); IR (neat, cm^{-1}): $\tilde{\nu}$ = 3271, 3063, 2924, 2851 (w), 1651 (s), 1563, 1470, 1404, 1292, 1149, 1080 (m), 998, 947 (w), 865 (m), 779, 732, 683 (s), 573 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 552 (100, M^+, $^{37}Cl_2$+$^{35}Cl_2$), 548 (12, M-4, $^{35}Cl_4$), 515 (19), 513 (18), 480 (19), 478 (14), 248 (15), 246 (23), 207 (25), 176 (29), 175 (13), 97 (17), 71 (23), 57 (32), 43 (27), 41 (17); HRMS (ESI-TOF): calcd. for $C_{30}H_{15}Cl_4O_2$ $[M-H]^+$: 546.983200; Found: 546.984200.

2,3,5,6-Tetrakis(3-fluorophenyl)cyclohexa-2,5-diene-1,4- dione (31m):



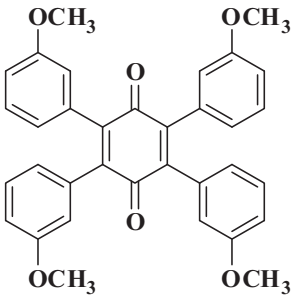
Starting from ***30*** (211 mg, 0.5 mmol), and ***26ab*** (280 mg, 2.0 mmol), ***31m*** was obtained (174 mg, 72 %), mp = 210-212 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 6.76-6.79 (m, 8H, H_{Ar}), 6.88-6.93 (m, 4H, H_{Ar}), 7.11-7.17 (m, 4H, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -112.9; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 115.8 ($J_{C,F}$ = 21.1 Hz, CH_{Ar}), 117.6 ($J_{C,F}$ = 23.4 Hz, CH_{Ar}), 126.3 ($J_{C,F}$ = 3.0 Hz, CH_{Ar}), 129.5 ($J_{C,F}$ = 8.3 Hz, CH_{Ar}), 134.1 ($J_{C,F}$ = 8.1 Hz, C_{Ar}), 142.4 ($J_{C,F}$ = 1.9 Hz, C_{Ar}), 162.1 ($J_{C,F}$ = 252.5 Hz, C_{Ar}), 185.5 (C=O); IR (neat): $\tilde{\nu}$ = 3274, 3079, 2922, 2851 (w), 1651, 1581 (s), 1483, 1432, 1317, 1266 (m), 1212 (s), 1160, 1111, 1043, 966, 904, 823 (m), 778, 683 (s), 587 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 487 (70), 486 (M^+, 100), 485 (26), 484 (50), 456 (13), 428 (15), 343 (12), 306 (20), 215 (16), 214 (58), 194 (12), 149 (13), 86 (23), 85 (12), 84 (40), 83 (12), 71 (18), 69 (20), 57 (27), 55 (16), 49 (38), 44 (19), 43 (21), 41 (16); HRMS (ESI-TOF): calcd. for $C_{30}H_{17}FO_2$ $[M+H]^+$: 485.115920; Found: 485.114570.

2,3,5,6-Tetrakis(3-(trifluoromethyl)phenyl)cyclohexa-2,5-diene-1,4- dione (31n):



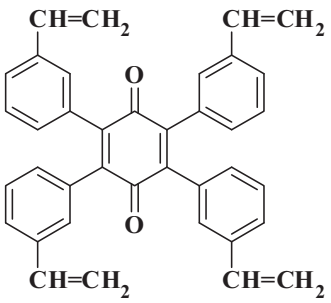
Starting from ***30*** (211 mg, 0.5 mmol), and ***26q*** (380 mg, 2.0 mmol), ***31n*** was obtained (220 mg, 64 %), mp = 232-234 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 7.20-7.25 (m, 8H, H_{Ar}), 7.33 (t, 4H, J = 7.8 Hz, H_{Ar}), 7.47 (d, 4H, J = 7.8 Hz, H_{Ar}); ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 123.5 ($J_{C,F}$ = 276.9 Hz, CF_3), 125.6 ($J_{C,F}$ = 14.6 Hz, CH_{Ar}), 127.5 ($J_{C,F}$ = 14.8 Hz), 128.6 (CH_{Ar}), 132.5 (C_{Ar}), 133.8 (CH_{Ar}), 142.7 (C_{Ar}), 185.1 (C=O); IR (neat): $\tilde{\nu}$ = 3272, 2919, 2849 (w), 1650 (m), 1614, 1489, 1425 (w), 1347 (m), 1262 (s), 1180 (m), 1180 (s), 1053 (m), 1002 (w), 952, 891, 801 (m), 688 (s), 648, 550 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 687 (77), 686 (M^+, 100), 684 (40), 667 (21), 666 (14), 665 (29), 656 (21), 228 (19), 616 (17), 615 (12), 323 (11), 315 (13), 314 (75), 313 (16), 295 (10), 69 (13), 57 (21), 43 (16); HRMS (EI): calcd. for $C_{34}H_{16}F_{12}O_2$ $[M]^+$: 684.095320; Found: 684.095497.

2,3,5,6-Tetrakis(3-methoxyphenyl)cyclohexa-2,5-diene-1,4- dione (31o):



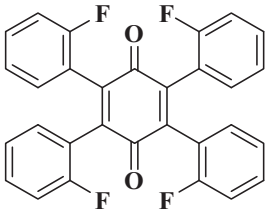
Starting from ***30*** (211 mg, 0.5 mmol), and ***26r*** (304 mg, 2.0 mmol), ***31o*** was obtained (232 mg, 87 %), mp = 247-249 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 5.22 (s, 12H, OCH_3), 6.57 (q, 4H, J = 2.5, 1.5, 0.9 Hz, H_{Ar}), 6.63 (dt, 4H, J = 7.6, 2.5, 1.5 Hz, H_{Ar}), 6.71 (dt, 4H, J = 7.9, 2.5, 0.9 Hz, H_{Ar}) 7.07 (t, 4H, J = 7.9, Hz, H_{Ar}); ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 55.2 (OCH_3), 114.6, 115.8, 123.2, 128.7 (CH_{Ar}), 142.9, 158.9 (C_{Ar}), 186.5 (C=O); IR (neat): $\tilde{\nu}$ = 3076, 3018, 2938, 2837 (w), 1650, 1578, 1484, 1430, 1313 (m), 1219 (s), 1182, 1125 (m), 1039 (s), 994 (m), 955, 905 (w), 853, 820 (m), 772, 692 (s), 597, 527 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 535 (33), 534 (M^+, 100), 532 (40), 239 (19), 199 (26), 191 (31), 169 (27), 165 (23), 163 (42), 150 (49), 135 (68), 121 (24), 57 (46), 44 (51), 43 (69), 41 (25); HRMS (ESI-TOF): calcd. for $C_{34}H_{28}NaO_6$ $[M+Na]^+$: 555.195870; Found: 555.195240.

2,3,5,6-Tetrakis(3-vinylphenyl)cyclohexa-2,5-diene-1,4- dione (31p):



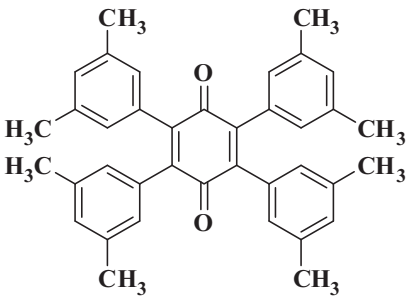
Starting from ***30*** (211 mg, 0.5 mmol), and ***26e*** (296 mg, 2.0 mmol), ***31p*** was obtained (160 mg, 62 %), mp = 161-163 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 5.09 (d, 4H, J = 10.9 Hz, $=CH_2$), 5.49 (d, 4H, J = 17.5 Hz, $=CH_2$), 6.51 (dd, 4H, J = 17.5, 10.9 Hz, =CH), 6.91 (d, 4H, J = 7.8 Hz, H_{Ar}), 7.07-7.18 (m, 12H, H_{Ar}); ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 114.3 ($=CH_2$), 126.2, 127.9, 128.8, 130.1 (CH_{Ar}), 132.4 (C_{Ar}), 136.3 (=CH), 137.0, 143.1 (C_{Ar}), 186.6 (C=O); IR (neat): $\tilde{\nu}$ = 3272, 3078 (w), 2925 (m), 1646 (s), 1553 (w), 1505, 1409, 1289 (m), 1212 (w), 1130, 1053, 986, 908 (m), 825 (s), 758 (m), 693 (s), 645 (w), 527 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 519 (46), 518 (M^+, 100), 517 (35), 516 (87), 488 (16), 460 (11), 414 (45), 413 (31), 382 (15), 230 (72), 226 (18), 215 (25), 202 (40); HRMS (EI): calcd. for $C_{38}H_{28}O_2$ $[M]^+$: 516.208380; Found: 516.207871.

2,3,5,6-Tetrakis(2-fluorophenyl)cyclohexa-2,5-diene-1,4- dione (31q):



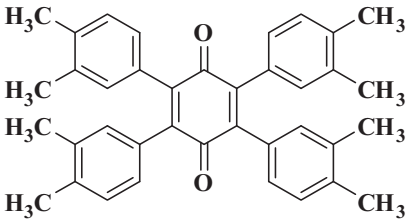
Starting from ***30*** (211 mg, 0.5 mmol), and ***26ac*** (280 mg, 2.0 mmol), ***31q*** was obtained (140 mg, 58 %), mp = 232-234 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 6.88-7.01 (m, 12H, H_{Ar}), 7.15-7.23 (m, 4H, H_{Ar}); ^{19}F-NMR (282 MHz, 298K, $CDCl_3$): δ = -111.4; ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 115.3 ($J_{C,F}$ = 17.5 Hz, CH_{Ar}), 120.7 ($J_{C,F}$ = 17.7 Hz), 123.7 (C_{Ar}), 130.9 ($J_{C,F}$ = 8.2 Hz, $2CH_{Ar}$), 141.3 ($J_{C,F}$ = 7.3 Hz, C_{Ar}), 159.7 ($J_{C,F}$ = 248.5 Hz, C_{Ar}), 181.1 (C=O); IR (neat): $\tilde{\nu}$ = 3289, 3083, 3012 (w), 1658 (s), 1579, 1479, 1317, 1262, 1213, 1143, 1093, 1025 (m), 971 (w), 921, 853, 808 (m), 743 (s), 684, 578 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 487 (31), 486 (M^+, 99), 484 (57), 456 (26), 428 (22), 361 (14), 312 (17), 215 (24), 214 (100), 194 (20), 193 (27), 184 (17); HRMS (EI): calcd. for $C_{30}H_{16}F_4O_2$ $[M]^+$: 484.108090; Found: 484.107789.

2,3,5,6-Tetrakis(3,5-dimethylphenyl)cyclohexa-2,5-diene-1,4- dione (31r):



Starting from ***30*** (211 mg, 0.5 mmol), and ***26n*** (300 mg, 2.0 mmol), ***31r*** was obtained (192 mg, 73 %), mp = 263-265 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 2.09 (s, 24H, $8CH_3$), 6.63 (s, 8H, H_{Ar}), 6.76 (s, 4H, H_{Ar}); ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 21.1 (CH_3), 128.4, 129.7 (CH_{Ar}), 132.7, 136.7, 143.0 (C_{Ar}), 187.4 (C=O); IR (neat): $\tilde{\nu}$ = 3267, 3002 (w), 2913 (m), 2860, 2734 (w), 1648 (s), 1601, 1462, 1376, 1332 (m), 1269 (w), 1239 (s), 1168 (w), 1099, 1037, 995, 937 (m), 878 (w), 840 (s), 781 (m), 692 (s), 601 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 527 (43), 526 (M^+, 100), 524 (31), 510 (15), 509 (29), 496 (21), 468 (14), 263 (17), 234 (44), 219 (25), 203 (30), 202 (15), 191 (16), 189 (15), 91 (9); HRMS (EI): calcd. for $C_{38}H_{36}O_6$ $[M]^+$: 524.270980; Found: 524.270641.

2,3,5,6-Tetrakis(3,4-dimethylphenyl)cyclohexa-2,5-diene-1,4- dione (31s):



Starting from ***30*** (211 mg, 0.5 mmol), and ***26ad*** (300 mg, 2.0 mmol), ***31s*** was obtained (207 mg, 79 %), mp = 224-226 °C. ^{1}H-NMR (300 MHz, 298K, $CDCl_3$): δ = 2.06, 2.10 (s, 24H, $8CH_3$), 6.69 (d, 4H, J = 7.8 Hz, H_{Ar}), 6.85 (m, 8H, H_{Ar}); ^{13}C-NMR (75 MHz, 298K, $CDCl_3$): δ = 19.6, 19.7 (CH_3), 128.2 (C_{Ar}), 128.9 (CH_{Ar}), 130.5 (C_{Ar}), 132.1, 135.5 (CH_{Ar}), 136.6, 142.6 (C_{Ar}), 187.5 (C=O); IR (neat): $\tilde{\nu}$ = 3260, 3019 (w), 2915 (m), 2728 (w), 1645 (s), 1607, 1557, 1495, 1446, 1379, 1313, 1223, 1177, 1111, 1068, 1019 (m), 958 (w), 896 (m), 814 (s), 758, 717, 659, 575 (m) cm^{-1}; Under the conditions of electronic ionization (EI), the compound was reduced to dihydrobenzoquinone; GC-MS (EI, 70 eV): m/z (%) 527 (45), 526 (M^+, 100), 524 (15), 503 (12), 502 (36), 500 (37), 406 (13), 277 (13), 243 (15), 234 (18), 231 (19), 229 (12), 220 (11), 219 (21), 215 (14), 205 (15), 203 (21), 202 (23), 157 (16), 133 (17), 105 (14), 91 (25), 77 (21), 44 (19), 43 (23), 41 (13); HRMS (EI): calcd. for $C_{38}H_{36}O_2$ $[M]^+$: 524.270980; Found: 524.271626.

Crystal Data and Structure Refinement

Crystal data and structure refinement for 12f (Chapter 1, figure 1.3)

Identification code	av_ih260	
Empirical formula	$C_{16}H_{13}FO_3$	
Formula weight	272.26	
Temperature	100(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	a = 12.9798(7) Å	α = 90°
	b = 8.9125(5) Å	β = 103.535 (3)°
	c = 11.1470(6) Å	γ = 90°
Volume	1253.70(12) $Å^3$	
Z	4	
Density (calculated)	1.442 Mg/m^3	
Absorption coefficient	0.109 mm^{-1}	
F(000)	568	
Crystal size	0.90 x 0.68 x 0.48 mm^3	
Θ range for data collection	2.80 to 32.61°	
Index ranges	$-19\leq h\leq 19$, $-11\leq k\leq 13$, $-16\leq l\leq 16$	
Reflections collected	28305	
Independent reflections	4541 [R(int) = 0.0423]	
Completeness to Θ = 32.61°	98.9 %	
Absorption correction	Semi-empirical from equivalents	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4541 / 0 / 207	
Goodness-of-fit on F^2	1.036	
Final R indices [$I>2\sigma(I)$]	R1 = 0.0464, wR2 = 0.1292	
R indices (all data)	R1 = 0.0554, wR2 = 0.1389	
Largest diff. peak and hole	0.672 and -0.293 $e.Å^{-3}$	

Crystal data and structure refinement for 12i (Chapter 1, figure 1.4)

Identification code	av_ih261	
Empirical formula	$C_{19}H_{20}O_5$	
Formula weight	328.35	
Temperature	133(2) K	
Wavelength	0.71073 Å	
Crystal system	Triclinic	
Space group (H.-M.)	$P\bar{1}$	
Space group (Hall)	-P 1	
Unit cell dimensions	a = 8.4322(4) Å	α = 92.961 (3)°
	b = 8.9442(5) Å	β = 102.855 (2)°
	c = 12.2612(6) Å	γ = 111.598 (3)°
Volume	829.11(7) $Å^3$	
Z	2	
Density (calculated)	1.315 Mg/m^3	
Absorption coefficient	0.095 mm^{-1}	
F(000)	348	
Crystal size	0.76 x 0.70 x 0.37 mm^3	
Θ range for data collection	2.48 to 29.00°.	
Index ranges	$-11 \leq h \leq 11$, $-12 \leq k \leq 12$, $-16 \leq l \leq 16$	
Reflections collected	17498	
Independent reflections	4380 [R(int) = 0.0375]	
Completeness to Θ = 29.00°	99.3 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.9657 and 0.9314	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4380 / 0 / 225	
Goodness-of-fit on F^2	1.076	
Final R indices [$I>2\sigma(I)$]	R1 = 0.0423, wR2 = 0.1153	
R indices (all data)	R1 = 0.0523, wR2 = 0.1254	
Largest diff. peak and hole	0.368 and -0.248 $e.Å^{-3}$	

Crystal data and structure refinement for 12l (Chapter 1, figure 1.5)

Identification code	av_ih251	
Empirical formula	$C_{18}H_{18}O_3$	
Formula weight	282.32	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	a = 13.842(13) Å	α = 90.00°
	b = 8.953(8) Å	β = 90.391 (17)°
	c = 11.429(10) Å	γ = 90.00°
Volume	1416(2) $Å^3$	
Z	4	
Density (calculated)	1.324 Mg/m^3	
Absorption coefficient	0.09 mm^{-1}	
F(000)	600	
Crystal size	0.31 × 0.26 × 0.16 mm^3	
Θ range for data collection	4.1 to 29.0°	
Index ranges	-18≤h≤18, -12≤k≤6, -14≤l≤15	
Reflections collected	13950	
Independent reflections	3738 [R(int) = 0.030]	
Completeness to Θ = 29.00°	99.0%	
Absorption correction	multi-scan	
Max. and min. transmission	0.973 and 0.986	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	2871 / 2 / 211	
Goodness-of-fit on F^2	1.07	
Final R indices [I>2σ(I)]	R1 = 0.049, wR2 = 0.147	
R indices (all data)	R1 = 0.0671, wR2 = 0.1468	
Largest diff. peak and hole	0.47and -0.23 e.$Å^{-3}$	

Crystal data and structure refinement for 12w (Chapter 1, figure 1.6)

Identification code	av_ih64	
Empirical formula	$C_{15}H_{13}NO_3$	
Formula weight	255.26	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group (H.-M.)	$P2_12_12_1$	
Space group (Hall)	P 2ac 2ab	
Unit cell dimensions	a = 4.997(4) Å	α = 90.00°
	b = 10.061(7) Å	β = 90.00°
	c = 24.039(17) Å	γ = 90.00°
Volume	1208.7(15) $Å^3$	
Z	4	
Density (calculated)	1.403 Mg m^{-3}	
Absorption coefficient	0.10 mm^{-1}	
F(000)	536	
Crystal size	0.45 × 0.23 × 0.11 mm^3	
Θ range for data collection	4.4–30.0°	
Index ranges	-3≤h≤6, -14≤k≤13, -32≤l≤33	
Reflections collected	7776	
Independent reflections	3484 [R(int) = 0.033]	
Completeness to Θ = 29.00°	99.2%	
Max. and min. transmission	0.9575 and 0.9882	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3018 / 0 / 178	
Goodness-of-fit on F^2	1.09	
Final R indices [I>2σ(I)]	R1 = 0.049, wR2 = 0.1199	
R indices (all data)	R1 = 0.0598, wR2 = 0.1266	
Largest diff. peak and hole	0.46and -0.26 e.$Å^{-3}$	

Crystal data and structure refinement for 17b (Chapter 2, figure 2.3)

Identification code	av_ih112	
Empirical formula	$C_{19}H_{22}O_3$	
Formula weight	298.37	
Temperature	296(2) K	
Wavelength	0.71073 Å	
Crystal system	Triclinic	
Space group (H.-M.)	$P\bar{1}$	
Space group (Hall)	-P 1	
Unit cell dimensions	a = 8.5474(5) Å	α = 107.400 (4)°
	b = 10.2756(5) Å	β = 109.658 (4)°
	c = 11.4019(10) Å	γ = 103.391 (3)°
Volume	836.16(10) $Å^3$	
Z	2	
Density (calculated)	1.185 Mg/m^3	
Absorption coefficient	0.079 mm^{-1}	
F(000)	320	
Crystal size	0.90 x 0.30 x 0.06 mm^3	
Θ range for data collection	2.24 to 28.07°	
Index ranges	$-11 \leq h \leq 11$, $-13 \leq k \leq 9$, $-14 \leq l \leq 15$	
Reflections collected	16851	
Independent reflections	3944 [R(int) = 0.0302]	
Completeness to Θ= 28.07°	96.8 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.9953 and 0.9324	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3944 / 0 / 226	
Goodness-of-fit on F^2	1.058	
Final R indices [$I>2\sigma(I)$]	R1 = 0.0597, wR2 = 0.1656	
R indices (all data)	R1 = 0.1173, wR2 = 0.2047	
Largest diff. peak and hole	0.228 and -0.234 $e.Å^{-3}$	

Crystal data and structure refinement for 17n (Chapter 2, figure, 2.4)

Identification code	av_ih-106	
Empirical formula	$C_{17}H_{14}ClF_3O_3$	
Formula weight	358.73	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/n$	
Space group (Hall)	-P 2yn	
Unit cell dimensions	a = 8.841(9) Å	α = 90.00°
	b = 8.097(8) Å	β = 91.56 (3)°
	c = 22.28(2) Å	γ = 90.00°
Volume	1594(3) $Å^3$	
Z	4	
Density (calculated)	1.494 Mg/m^3	
Absorption coefficient	0.28 mm^{-1}	
F(000)	736	
Crystal size	0.50 x 0.68 x 0.01 mm^3	
Θ range for data collection	3.9 to 27.5°	
Index ranges	-11≤h≤11, -10≤k≤6, -25≤l≤28	
Reflections collected	14465	
Independent reflections	3650 [R(int) = 0.053]	
Completeness to Θ = 29.00°	99.6%	
Absorption correction	phi and ω scans	
Max. and min. transmission	0.8779 and 0.9915	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	2105 / 0 / 234	
Goodness-of-fit on F^2	1.00	
Final R indices [I>2σ(I)]	R1 = 0.053, wR2 = 0.1233	
R indices (all data)	R1 = 0.1151, wR2 = 0.1390	
Largest diff. peak and hole	0.307 and -0.350 $e.Å^{-3}$	

Crystal data and structure refinement for 20b (Chapter 2, figure 2.5)

Identification code	av_ms304	
Empirical formula	$C_{21}H_{18}O_3$	
Formula weight	318.35	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	*C*2/*c*	
Space group (Hall)	-C 2yc	
Unit cell dimensions	a = 16.472(19) Å	α = 90.00°
	b = 11.446(13) Å	β = 114.74 (3)°
	c = 19.19(3) Å	γ = 90.00°
Volume	3287(7) $Å^3$	
Z	8	
Density (calculated)	1.287 Mg/m^3	
Absorption coefficient	0.09 mm^{-1}	
F(000)	1344	
Crystal size	0.99 × 0.43 × 0.04 mm^3	
Θ range for data collection	2.3 to 30.0°	
Index ranges	-23≤h≤23, -16≤k≤16, -27≤l≤26	
Reflections collected	22034	
Independent reflections	4785 [R(int) = 0.033]	
Completeness to Θ = 29.00°	99.9%	
Absorption correction	phi and psi scans	
Max. and min. transmission	0.920 and 0.997	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3512 / 0 / 223	
Goodness-of-fit on F^2	1.05	
Final R indices [I>2σ(I)]	R1 = 0.0460, wR2 = 0.1195	
R indices (all data)	R1 = 0.0708, wR2 = 0.1283	
Largest diff. peak and hole	0.32and -0.22 e.$Å^{-3}$	

Crystal data and structure refinement for 24e (Chapter 3, figure 3.4)

Identification code	is_ih279a	
Empirical formula	$C_{26}H_{26}O_4$	
Formula weight	402.47	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	a = 18.0324(6) Å	α = 90.00°
	b = 9.6251(3) Å	β = 112.030 (1)°
	c = 13.7250(4) Å	γ = 90.00°
Volume	2208.23(12) $Å^3$	
Z	4	
Density (calculated)	1.211 Mg/m^3	
Absorption coefficient	0.08 mm^{-1}	
F(000)	856	
Crystal size	0.52 × 0.33 × 0.11 mm^3	
Θ range for data collection	2.4 to 29.0°	
Index ranges	-24≤h≤22, -12≤k≤13, -13≤l≤18	
Reflections collected	23223	
Independent reflections	5863 [R(int) = 0.028]	
Completeness to Θ = 29.00°	99.9%	
Absorption correction	phi and psi scans	
Max. and min. transmission	0.959 and 0.991	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4089 / 0 / 277	
Goodness-of-fit on F^2	1.04	
Final R indices [I>2σ(I)]	R1 = 0.0433, wR2 = 0.0994	
R indices (all data)	R1 = 0.0722, wR2 = 0.1088	
Largest diff. peak and hole	0.23and -0.21 e.$Å^{-3}$	

Crystal data and structure refinement for 24k (Chapter 3, figure 3.5)

Identification code	av_ih276a	
Empirical formula	$C_{28}H_{16}F_2$	
Formula weight	390.41	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	a = 10.2130(3) Å	α = 90.00 °
	b = 10.2110(2) Å	β = 103.783 (2)°
	c = 19.2730(4) Å	γ = 90.00 °
Volume	1952.01(8) $Å^3$	
Z	4	
Density (calculated)	1.328 Mg/m^3	
Absorption coefficient	0.09 mm^{-1}	
F(000)	808	
Crystal size	0.43 × 0.41 × 0.19 mm^3	
Θ range for data collection	2.2 to 29.7°	
Index ranges	-13≤h≤14, -13≤k≤14, -26≤l≤25	
Reflections collected	19847	
Independent reflections	5533 [R(int) = 0.025]	
Completeness to Θ = 29.00°	99.5%	
Absorption correction	phi and psi scans	
Max. and min. transmission	0.963 and 0.983	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3899 / 0 / 271	
Goodness-of-fit on F^2	1.04	
Final R indices [I>2σ(I)]	R1 = 0.0427, wR2 = 0.1040	
R indices (all data)	R1 = 0.0702, wR2 = 0.1143	
Largest diff. peak and hole	0.21and -0.21 e.$Å^{-3}$	

Crystal data and structure refinement for 27j (Chapter 4, figure 4.5)

Identification code	is_ih310	
Empirical formula	$C_{17}H_{10}BrF_3$	
Formula weight	351.16	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/n$	
Space group (Hall)	-P 2yn	
Unit cell dimensions	a = 12.6672(2) Å	α = 90.00 °
	b = 5.6630(1) Å	β = 100.732 (1)°
	c = 19.8068(4) Å	γ = 90.00 °
Volume	1395.98(4) $Å^3$	
Z	4	
Density (calculated)	1.671 Mg/m^3	
Absorption coefficient	2.97 mm^{-1}	
F(000)	696	
Crystal size	0.36 × 0.35 × 0.20 mm^3	
Θ range for data collection	2.1 to 30.0°	
Index ranges	-17≤h≤17, -7≤k≤6, -27≤l≤27	
Reflections collected	15740	
Independent reflections	4046 [R(int) = 0.020]	
Completeness to Θ = 29.00°	99.8%	
Absorption correction	phi and psi scans	
Max. and min. transmission	0.415 and 0.588	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3266 / 0 / 190	
Goodness-of-fit on F^2	1.04	
Final R indices [I>2σ(I)]	R1 = 0.0279, wR2 = 0.0654	
R indices (all data)	R1 = 0.0407, wR2 = 0.681	
Largest diff. peak and hole	0.38and −0.45e.$Å^{-3}$	

Crystal data and structure refinement for 27l (Chapter 4, figure 4.6)

Identification code	is_ih321f	
Empirical formula	$C_{15}H_{12}BrF_3O_2$	
Formula weight	361.16	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	a = 12.7392(4) Å	α = 90.00°
	b = 12.6469(4) Å	β = 90.501 (2)°
	c = 35.6429(9) Å	γ = 90.00°
Volume	5742.3(3) $Å^3$	
Z	16	
Density (calculated)	1.671 Mg/m^3	
Absorption coefficient	2.90 mm^{-1}	
F(000)	2880	
Crystal size	0.33 × 0.27 × 0.16 mm^3	
Θ range for data collection	1.6 to 30.6°.	
Index ranges	-18≤h≤15, -14≤k≤18, -51≤l≤48	
Reflections collected	67695	
Independent reflections	17583 [R(int) = 0.055]	
Completeness to Θ = 29.00°	99.1%	
Absorption correction	phi and psi scans	
Max. and min. transmission	0.448 and 0.654	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	9349 / 0 / 765	
Goodness-of-fit on F^2	1.02	
Final R indices [I>2σ(I)]	R1 = 0.0541, wR2 = 0.0957	
R indices (all data)	R1 = 0.1333, wR2 = 0.1089	
Largest diff. peak and hole	0.50 and -0.83 $e.Å^{-3}$	

Crystal data and structure refinement for 28i (Chapter 4, figure 4.7)

Identification code	is_ih321a	
Empirical formula	$C_{23}H_{21}F_3$	
Formula weight	354.40	
Temperature	173 K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	a = 15.6303(3) Å	α = 90.00°
	b = 14.2554(3) Å	β = 104.176 (1)°
	c = 8.5015(1) Å	γ = 90.00°
Volume	1836.59(6) $Å^3$	
Z	4	
Density (calculated)	1.282 Mg/m^3	
Absorption coefficient	0.09 mm^{-1}	
F(000)	744	
Crystal size	0.38 × 0.38 × 0.34 mm^3	
Θ range for data collection	2.7 to 30.0°	
Index ranges	-16≤h≤21, -20≤k≤19, -11≤l≤11	
Reflections collected	20905	
Independent reflections	5329 [R(int) = 0.021]	
Completeness to Θ = 29.00°	99.8%	
Absorption correction	phi and psi scans	
Max. and min. transmission	0.965 and 0.969	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4183 / 0 / 239	
Goodness-of-fit on F^2	1.08	
Final R indices [I>2σ(I)]	R1 = 0.0425, wR2 = 0.1228	
R indices (all data)	R1 = 0.0574, wR2 = 0.1316	
Largest diff. peak and hole	0.35and -0.24 e.$Å^{-3}$	

Crystal data and structure refinement for 28m (Chapter 4, figure 4.8)

Identification code	av_ih309b	
Empirical formula	$C_{23}H_{21}F_3O_4$	
Formula weight	418.40	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Triclinic	
Space group (H.-M.)	$P\bar{1}$	
Space group (Hall)	-P 1	
Unit cell dimensions	a = 8.5019(2) Å	α = 94.766 (1)°
	b = 11.4805(2) Å	β = 111.198 (1)°
	c = 1.6049(3) Å	γ = 106.453 (1)°
Volume	990.79(4) $Å^3$	
Z	2	
Density (calculated)	1.402 Mg/m^3	
Absorption coefficient	0.11 mm^{-1}	
F(000)	436	
Crystal size	0.35 × 0.21 × 0.09 mm^3	
Θ range for data collection	2.4 to 30.0°	
Index ranges	-11≤h≤11, -15≤k≤16, -16≤l≤16	
Reflections collected	20813	
Independent reflections	5743 [R(int) = 0.025]	
Completeness to Θ = 29.00°	99.5%	
Absorption correction	phi and psi scans	
Max. and min. transmission	0.961 and 0.990	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4525 / 0 / 275	
Goodness-of-fit on F^2	1.074	
Final R indices [I>2σ(I)]	R1 = 0.047, wR2 = 0.1172	
R indices (all data)	R1 = 0.0627, wR2 = 0.1284	
Largest diff. peak and hole	0.37and -0.23 e.$Å^{-3}$	

Crystal data and structure refinement for 29b (Chapter 4, figure 4.9)

Identification code	av_ih337	
Empirical formula	$C_{25}H_{19}F_3O_2$	
Formula weight	408.40	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Triclinic	
Space group (H.-M.)	$P\bar{1}$	
Space group (Hall)	-P 1	
Unit cell dimensions	a = 7.3455(2) Å	α = 79.346 (1)°
	b = 11.0179(3) Å	β = 84.382 (1)°
	c = 13.2235(3) Å	γ = 72.771 (1)°
Volume	1003.50(4) $Å^3$	
Z	2	
Density (calculated)	1.352 Mg/m^3	
Absorption coefficient	0.10 mm^{-1}	
F(000)	424	
Crystal size	0.43 × 0.33 × 0.26 mm^3	
Θ range for data collection	2.0 to 30.0°	
Index ranges	-9≤h≤10, -15≤k≤15, -18≤l≤17	
Reflections collected	20950	
Independent reflections	5790 [R(int) = 0.019]	
Completeness to Θ = 29.00°	99.0%	
Absorption correction	phi and psi scans	
Max. and min. transmission	0.957 and 0.974	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4634 / 0 / 310	
Goodness-of-fit on F^2	1.09	
Final R indices [I>2σ(I)]	R1 = 0.0645, wR2 = 0.1324	
R indices (all data)	R1 = 0.0591, wR2 = 0.1397	
Largest diff. peak and hole	0.370and -0.235 e.$Å^{-3}$	

Crystal data and structure refinement for 29c (Chapter 4, figure 4.10)

Identification code	av_ih335b	
Empirical formula	$C_{21}H_{16}F_4O_2$	
Formula weight	376.34	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	a = 9.0761(3) Å	α = 90.00°
	b = 20.6455(7) Å	β = 90.856 (2)°
	c = 9.3035(3) Å	γ = 90.00°
Volume	1743.10(10) $Å^3$	
Z	4	
Density (calculated)	1.434 Mg/m^3	
Absorption coefficient	0.12 mm^{-1}	
F(000)	776	
Crystal size	0.31 × 0.18 × 0.16 mm^3	
Θ range for data collection	2.2 to 28.9°	
Index ranges	-12≤h≤12, -28≤k≤27, -12≤l≤12	
Reflections collected	17914	
Independent reflections	4599 [R(int) = 0.036]	
Completeness to Θ = 29.00°	97.7%	
Absorption correction	phi and psi scans	
Max. and min. transmission	0.964 and 0.981	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3156 / 0 / 246	
Goodness-of-fit on F^2	1.04	
Final R indices [I>2σ(I)]	R1 = 0.0455, wR2 = 0.1064	
R indices (all data)	R1 = 0.0756, wR2 = 0.1164	
Largest diff. peak and hole	0.64and -0.25 e.$Å^{-3}$	

Crystal data and structure refinement for 31a (Chapter 5, figure 5.3)

Identification code	av_ihpd1r	
Empirical formula	$C_{30}H_{20}O_2$	
Formula weight	412.46	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	a = 5.8993(4) Å	α = 90.00°
	b = 11.9855(8) Å	β = 92.205 (4)°
	c = 14.9886(8) Å	γ = 90.00°
Volume	1059.00(12) $Å^3$	
Z	2	
Density (calculated)	1.293 Mg/m^3	
Absorption coefficient	0.08 mm^{-1}	
F(000)	432	
Crystal size	0.46 × 0.23 × 0.05 mm^3	
Θ range for data collection	2.7 to 29.9°	
Index ranges	-8≤h≤7, -16≤k≤14, -21≤l≤20	
Reflections collected	11972	
Independent reflections	3063 [R(int) = 0.033]	
Completeness to Θ = 29.00°	99.9%	
Absorption correction	phi and psi scans	
Max. and min. transmission	0.964 and 0.994	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	2121 / 0 / 145	
Goodness-of-fit on F^2	1.05	
Final R indices [I>2σ(I)]	R1 = 0.0464, wR2 = 0.1040	
R indices (all data)	R1 = 0.0781, wR2 = 0.1143	
Largest diff. peak and hole	0.29 and -0.19 $e.Å^{-3}$	

Crystal data and structure refinement for 31c (Chapter 5, figure 5.4)

Identification code	av_pd5	
Empirical formula	$C_{38}H_{36}O_2$	
Formula weight	524.67	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/n$	
Space group (Hall)	-P 2yn	
Unit cell dimensions	a = 13.67(5) Å	α = 90.00°
	b = 9.112(18) Å	β = 101.82 (8)°
	c = 23.98(4) Å	γ = 90.00°
Volume	2924(13) $Å^3$	
Z	4	
Density (calculated)	1.192 Mg/m^3	
Absorption coefficient	0.07 mm^{-1}	
F(000)	1120	
Crystal size	1.55 × 0.29 × 0.26 mm^3	
Θ range for data collection	3.2 to 29.0°	
Index ranges	-18≤h≤18, -10≤k≤12, -26≤l≤32	
Reflections collected	29556	
Independent reflections	7762 [R(int) = 0.029]	
Completeness to Θ = 29.00°	99.7%	
Absorption correction	ω scans	
Max. and min. transmission	0.897 and 0.982	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	6301 / 0 / 377	
Goodness-of-fit on F^2	1.10	
Final R indices [I>2σ(I)]	R1 = 0.0477, wR2 = 0.1287	
R indices (all data)	R1 = 0.0601, wR2 = 0.1361	
Largest diff. peak and hole	0.34 and -0.29 e.$Å^{-3}$	

Crystal data and structure refinement for 31i (Chapter 5, figure 5.5)

Identification code	is_ihpd68	
Empirical formula	$C_{34}H_{16}F_{12}O_6$	
Formula weight	748.47	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	a = 11.6276(5) Å	α = 90.00°
	b = 10.4706(5) Å	β = 90.102 (2)°
	c = 12.9367(5) Å	γ = 90.00°
Volume	1575.01(12) $Å^3$	
Z	2	
Density (calculated)	1.578 Mg/m^3	
Absorption coefficient	0.15 mm^{-1}	
F(000)	752	
Crystal size	0.90 × 0.52 × 0.12 mm^3	
Θ range for data collection	2.5 to 29.0°	
Index ranges	-11≤h≤15, -13≤k≤14, -17≤l≤15	
Reflections collected	16713	
Independent reflections	4174 [R(int) = 0.022]	
Completeness to Θ = 29.00°	99.7 %	
Absorption correction	phi and psi scans	
Max. and min. transmission	0.874 and 0.982	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3447 / 6 / 306	
Goodness-of-fit on F^2	1.07	
Final R indices [I>2σ(I)]	R1 = 0.0392, wR2 = 0.1099	
R indices (all data)	R1 = 0.0491, wR2 = 0.1159	
Largest diff. peak and hole	0.33 and -0.25 e.$Å^{-3}$	

Crystal data and structure refinement for 31q (Chapter 5, figure 5.6)

Identification code	is_ihpd70	
Empirical formula	$C_{30}H_{16}F_4O_2$	
Formula weight	484.43	
Temperature	173 K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1$	
Space group (Hall)	P 2yb	
Unit cell dimensions	a = 6.7236(2) Å	α = 90.00°
	b = 11.1670(3) Å	β = 90.172 (1)°
	c = 4.7134(4) Å	γ = 90.00°
Volume	1104.71(5) $Å^3$	
Z	2	
Density (calculated)	1.456 Mg/m^3	
Absorption coefficient	0.11 mm^{-1}	
F(000)	496	
Crystal size	0.45 × 0.40 × 0.23 mm^3	
Θ range for data collection	1.8 to 28.0°	
Index ranges	-8≤h≤8, -14≤k≤14, -19≤l≤19	
Reflections collected	11851	
Independent reflections	5274 [R(int) = 0.018]	
Completeness to Θ = 29.00°	99.8 %	
Absorption correction	phi and psi scans	
Max. and min. transmission	0.951 and 0.974	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4305 / 1 / 349	
Goodness-of-fit on F^2	1.08	
Final R indices [I>2σ(I)]	R1 = 0.0462, wR2 = 0.1247	
R indices (all data)	R1 = 0.0602, wR2 = 0.1378	
Largest diff. peak and hole	0.66 and -0.22 $e.Å^{-3}$	

Abbreviations

Ac	Acetyl
Anal	Elemental Analysis
Ar	Aromatic
bp	Boiling point
calcd	Calculated
CI	Chemical Ionization
COSY	Correlated Spectroscopy
DEPT	Distortionless Enhancement by Polarization Transfer
dr	Diastereomeric ratio
ee	Enantiomeric excess
EI	Electron Impact (Electronic Ionization)
ESI	Electrospray Ionization
Et_2O	Diethyl ether
EtOH	Ethanol
GC	Gas Chromatography
GP	General Procedure
HMBC	Heteronuclear Multiple Bond Correlation
HPLC	High Performance Liquid Chromatography
HRMS	High Resolution Mass Spectrometry
IR	Infrared Spectroscopy
LDA	Lithium diisopropylamide
Me_3SiCl	Trimethylsilyl chloride
MS	Mass Spectrometry
mp	Melting point
NaOEt	Sodium ethanolate
*n*BuLi	*n*-Butyllithium
NEt_3	Triethylamine
NMR	Nuclear Magnetic Resonance
NOESY	Nuclear Overhauser and Exchange Spectroscopy
ORTEP	Oak Ridge Thermal Ellipsoid Plot
OTf	Triflate

Ph	Phenyl
ppm	Parts per million
R_f	Retention factor
Tf_2O	Trifluoromethanesulfonic anhydride (triflic anhydride)
TFA	Trifluoroacetic acid
THF	Tetrahydrofuran
TLC	Thin Layer Chromatography
TMS	Tetramethylsilane
Tol	Tolyl (p-MeC_6H_4)
Tos	Tosyl (p-$MeC_6H_4SO_2$)
UV	Ultraviolet Spectroscopy

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