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Copper-Catalyzed Double Intramolecular Ullmann Coupling for the Synthesis of Diastereomerically and Enantiomerically Pure 4b,9b-Dihydrobenzofuro-[3,2-*b*]benzofurans

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The copper-catalyzed double intramolecular Ullmann coupling of *syn*-1,2-bis(2-bromoaryl)ethane-1,2-diols with catalytic amounts of Cu^{II} oxinate as the copper source, K_3PO_4 as a base, and KI as a reductant in aqueous acetonitrile selectively delivers 4b,9b-dihydrobenzofuro[3,2-*b*]benzofurans in diastereomerically and enantiomerically pure form and yields of up to 90 %. The substrates can be obtained in both diastereomerically and enantiomerically pure form by catalytic dihydroxylation of the corresponding (*E*)-stilbenes.

Introduction

The copper-catalyzed Ullmann coupling[1] has been developed into an important synthetic tool for efficient *O*-arylation with aryl halides. The method allows the formation of diaryl ethers as well as the synthesis of alkyl aryl ethers in high yields.[2] As well as intermolecular couplings, copper-catalyzed intramolecular *O*-arylations are also known.[3] They allow the synthesis of a number of *O*-heterocycles, including benzo[*b*]furans,[3a] 2,3-dihydrobenzofurans,[3b] 1,2-benzisoxazoles,[3c] benzo[*d*]oxazoles,[3d–3f] 4*H*-1-benzopyrans,[3g] chromans,[3b] 2,3-dihydro-1,4-benzoxazines,[3h] 9*H*-xanthene-9-ones,[3i] 2,3,4,9-tetrahydro-1*H*-xanthen-1-ones,[3j] 2,3,4,9-tetrahydro-benzoxazocines,[3k] and 12*H*-chromeno[2,3-*b*]quinolin-12-ones.[3l] Furthermore, it has been established that copper-catalyzed *O*-arylations can be combined with other transformations in domino reactions.[4] This approach has proved valuable for the preparation of numerous heterocyclic systems.[5] Some typical examples include benzofurans,[5a] benzoxazoles,[5b,5c] spirocyclic oxindoles,[5d–5f] 3,4-dihydrodibenzo[*b*,*d*]furan-1(2*H*)-ones,[5g] 4*H*-chromenes,[5h,1] 1,4-benzodioxanes,[5j] 1,4-benzoxazines,[5j] 1,4-benzoxathiines,[5k] and dibenzoxazepinones.[5l] In contrast, the use of chiral substrates in inter- as well as intramolecular copper-catalyzed *O*-arylations has been investigated less.[6] Another research area that has not been fully developed is that of double Ullmann couplings. A few examples of intermolecular double couplings are known,[7] such as the reaction of aryl dihalides with two *O*-nucleophiles or two *N*-nucleophiles, and the reaction of dinucleophiles with two aryl halides. Only isolated cases of transition-metal-catalyzed intramolecular diarylations of diols, diamines, and related compounds have been reported to date.[8]

Some natural products containing a 4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran moiety are known, including the anti-inflammatory baeckeins F–I from the roots of *Baeckea frutescens*,[9a] and cyclorocaglamide from *Aglaia oligophylla*.[9b] Synthetic 4b,9b-dihydrobenzofuro[3,2-*b*]benzofurans have been shown to have remarkable photochromic properties.[10a,10b] Other 4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran derivatives are useful ligands for the Pd-catalyzed telomerization of 1,3-butadiene and methanol,[10c] as well as the Rh-catalyzed carbonylation of methanol.[10d] Only a few synthetic methods are available for the preparation of the 4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran skeleton.[10] They include the Claisen rearrangement of 1,4-diaryloxy-2-butynes,[10a,10b,11a–11c] the oxidative cyclization of 2,2′-dihydroxystilbenes[11d–11f] and 8,8′-hydroxylated binaphthols,[11g] the reductive coupling/cyclization of 2-hydroxyacetophenones[11h] and 2-hydroxybenzaldehydes,[11i] and the condensation between glyoxal and *p*-cresol.[11j]

In this paper, we present a new approach to the synthesis of bisannulated bisheterocyclic systems. Our approach involves a double intramolecular cyclization of 1,2-bis(2-haloaryl)-substituted 1,2-bisnucleophiles **A**, such as 1,2-diols, 1,2-disulfides, 1,2-diamines, 1,2-amino alcohols, 1,2 aminothiols, and similar substrates, to give **B** (Scheme 1). Obviously, the double intramolecular cyclizations are not restricted to 1,2-bis(2-haloaryl)-substituted 1,2-bisnucleophiles **A**, but can also be applied to a multitude of other bis(2-haloaryl)-substituted bisnucleophiles **C** (Scheme 1).

In this study, we demonstrate that this concept can be realized, using the copper-catalyzed double intramolecular

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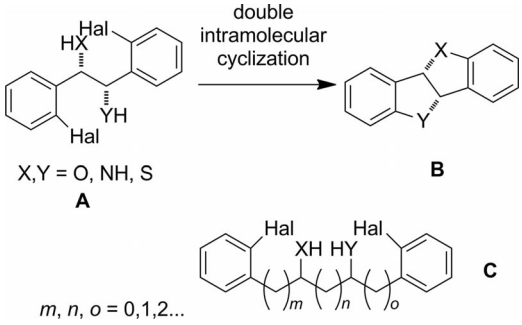
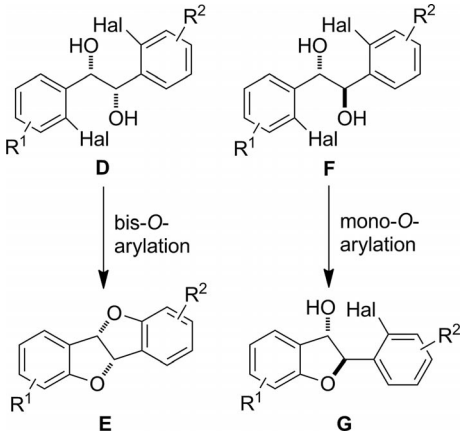


Scheme 1. The double intramolecular heteroarylation of *syn*-1,2-bis(2-haloaryl)substituted 1,2-bisnucleophiles and related substrates – a new approach to the synthesis of bisannulated bisheterocyclic systems.

Ullmann coupling of *syn*-1,2-bis(2-haloaryl)ethane-1,2-diols **D** to give 4b,9b-dihydrobenzo[3,2-*b*]furobenzofurans **E** as an example. It was envisaged that only *syn*-1,2-bis(2-haloaryl)ethane-1,2-diols **D** would undergo intramolecular bis-*O*-arylation to give **E**; *anti*-1,2-bis(2-haloaryl)ethane-1,2-diols **F** were expected to deliver the products of intramolecular mono-*O*-arylation **G** (Scheme 2).

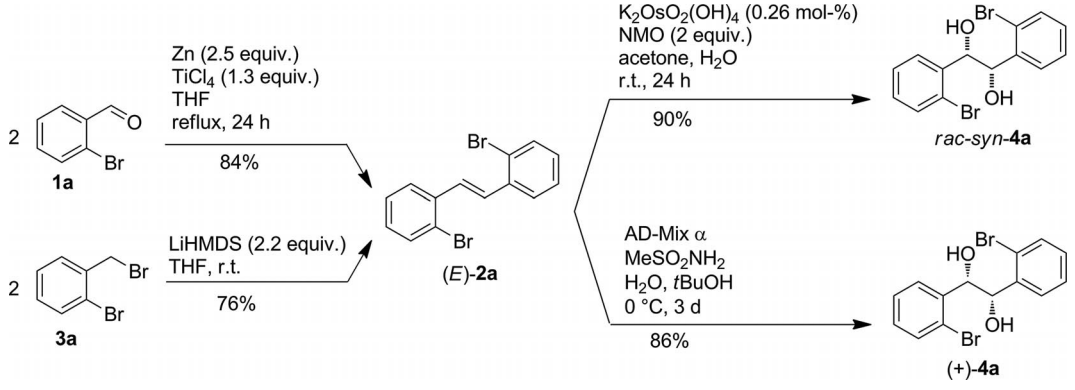


Scheme 2. Bis-*O*-arylation of *syn*-1,2-bis(2-haloaryl)ethane-1,2-diols and mono-*O*-arylation of *anti*-1,2-bis(2-haloaryl)ethane-1,2-diols.

Results and Discussion

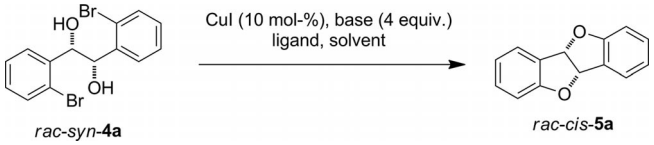
The reaction of *syn*-1,2-bis(2-bromophenyl)ethane-1,2-diol (*syn*-**4a**) to give 4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (**5a**) was chosen as the model reaction. This substrate is particularly suitable since it can easily be obtained in racemic as well as enantiomerically pure form by dihydroxylation of the corresponding (*E*)-stilbene [i.e., (*E*)-**2a**]. For the synthesis of symmetrical as well as unsymmetrical substituted (*E*)-stilbenes, a number of procedures, such as the McMurry coupling,[12] the homocoupling of benzyl halides,[13] and the Wittig–Horner olefination have been established.[14] The required (*E*)-stilbene [i.e., (*E*)-**2a**] was obtained either by McMurry coupling of 2-bromobenzaldehyde (**1a**) in 84% yield, or by homocoupling of 2-bromobenzyl bromide (**3a**) in 76% yield (Scheme 3). Upjohn dihydroxylation[15] of *E*-**2a** with $K_2OsO_2(OH)_4$ (0.26 mol-%) and *N*-methylmorpholine *N*-oxide (NMO; 2 equiv.) delivered racemic 1,2-diol *rac*-*syn*-**4a** in 90% yield. Enantiomerically pure 1,2-diol (+)-*syn*-**4a** was prepared in 86% yield using the enantioselective Sharpless dihydroxylation.[16]

With the model substrates in hand, the copper-catalyzed double intramolecular Ullmann coupling was studied. For this purpose, *rac*-*syn*-**4a** was subjected to conditions that have proved successful for intramolecular *O*-arylations,[3] i.e., with CuI (10 mol-%), an additive (20 mol-%), such as 8-hydroxyquinoline, DMEDA (*N*,*N*′-dimethylethylenediamine), or 1,10-phenanthroline, and a base (4 equiv.), like Cs_2CO_3, K_3PO_4, or K_2CO_3, in toluene as a solvent at 110 °C for 3 d (Table 1, entries 1–6). The outcome of these initial experiments was disappointing, since the yield of the double Ullmann product did not exceed 5%. It turned out that the polarity of the solvent plays a crucial role. When the reactions were run in the polar aprotic solvent DMF, the yields improved considerably. The reaction of *rac*-*syn*-**4a** with CuI (10 mol-%), Cs_2CO_3 (4 equiv.), and 8-hydroxyquinoline (20 mol-%) in DMF delivered *rac*-*cis*-**5a** in 34% yield after 3 d at 120 °C (Table 1, entry 7). The reaction time could be shortened from 72 h to 2 h without a significant decrease of the yield (Table 1, entry 8). In the absence of any ligand, *rac*-*cis*-**5a** was formed in 21% yield (Table 1,



Scheme 3. Synthesis of *syn*-1,2-bis(2-bromophenyl)ethane-1,2-diol (**4a**) in racemic as well as enantiomerically pure form. LiHMDS = lithium hexamethyldisilazide.

Table 1. Optimization of the reaction of *rac-syn*-**4a** using CuI as the catalyst.[a]



rac-syn-**4a** *rac-cis*-**5a**

Entry	Base	Ligand (mol-%)	Solvent	*T* [°C]	Time [h]	Yield of *rac-cis*-**5a** [%]
1	Cs_2CO_3	8-hydroxyquinoline (20)	toluene	110	72	5
2	K_3PO_4	8-hydroxyquinoline (20)	toluene	110	72	1
3	Cs_2CO_3	DMEDA (20)	toluene	110	72	1
4	Cs_2CO_3	1,10-phenanthroline (20)	toluene	110	72	2
5	K_2CO_3	8-hydroxyquinoline (20)	toluene	110	72	–
6	Na_2CO_3	8-hydroxyquinoline (20)	toluene	110	72	–
7	Cs_2CO_3	8-hydroxyquinoline (20)	DMF	120	72	34
8	Cs_2CO_3	8-hydroxyquinoline (20)	DMF	120	2	31
9	Cs_2CO_3	–	DMF	120	2	21
10	Cs_2CO_3	–	DMF	25	72	–
11	Cs_2CO_3	8-hydroxyquinoline (20)	DMF	25	72	–
12	Cs_2CO_3	8-hydroxyquinoline (20)	NMP	120	72	20
13	Cs_2CO_3	8-hydroxyquinoline (20)	H_2O	120	72	51
14	K_3PO_4	8-hydroxyquinoline (20)	H_2O	120	72	48
15	K_3PO_4	8-hydroxyquinoline (20)	CH_3CN	120	72	47
16	K_3PO_4	8-hydroxyquinoline (20), molecular sieves (4 Å)	CH_3CN	120	72	56
17	K_3PO_4	8-hydroxyquinoline (20)	CH_3CN/H_2O, 1:1	120	72	68

[a] In all cases, 0.5 mmol of *rac-syn*-**4a** was used.

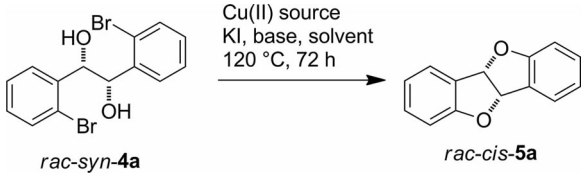
entry 9). Decreasing the reaction temperature to room temperature was counterproductive (Table 1, entries 10 and 11). Subsequently, the influence of solvent and base was studied in more detail.

With Cs_2CO_3 as the base, the yield increased to 51% when the reaction was run in H_2O (Table 1, entry 13). A similar yield was achieved when Cs_2CO_3 was replaced with K_3PO_4 as the base (Table 1, entry 14). Since K_3PO_4 is a much cheaper base than Cs_2CO_3, all further reactions were run with K_3PO_4. The reaction with K_3PO_4 as the base could also be run in CH_3CN without an appreciable drop in the yield (Table 1, entry 15). Interestingly, the yield improved slightly to 56% when the transformation was carried out in the presence of molecular sieves (4 Å) (Table 1, entry 16). More remarkably, the yield increased to 68% when the transformation was run in a mixture of CH_3CN and H_2O (1:1 v/v), which forms a two-phase system under these conditions (Table 1, entry 17). All further experiments were therefore carried out in a 1:1 mixture of water and an organic solvent.

The results presented in Table 1 show that the combination of CuI (10 mol-%) as the copper source and 8-hydroxyquinoline as the ligand is suitable for the intramolecular bis-*O*-arylation of the model compound. So far, the Cu^I salt/8-hydroxyquinoline system has been used for the arylation of KOH[17a] and nBu$_4$NOH,[17b] of aliphatic alcohols,[3b] and also of phenols.[17c] We wondered whether the Cu^I catalyst could be replaced by a combination of a Cu^{II} compound and a reductant (Table 2). For this purpose, *rac-syn*-**4a** was treated with a combination of $CuSO_4$ (10 mol-%) and KI (4 equiv.) in the absence of any further ligand under the conditions of Table 1, entry 17. To our delight, the yield of *rac-cis*-**5a** improved to 81% (Table 2, entry 1). It seems reasonable to suppose that KI acts to reduce Cu^{2+} to Cu^+.[18] However, *rac-cis*-**5a** was also formed in 61% yield in the absence of KI (Table 2, entry 2).

A further increase in the yield of *rac-cis*-**5a** was achieved when $CuSO_4$ was replaced with copper bis(8-hydroxyquinolate), also known as Cu^{II} oxinate.[19] Cu^{2+} can form a variety of complexes with 8-hydroxyquinoline as a ligand.[19a,19b] Depending on the reaction conditions, complexes with one or two molecules of 8-hydroxyquinoline are obtained.[19b] In the presence of strongly coordinating anions like F^-, Cl^-, or Br^-, the formation of complexes of the type $Cu(C_9H_6NO)X$ (X = F^-, Cl^-, or Br^-) is observed, while in the absence of such anions $Cu(C_9H_6NO)_2$ and $Cu(C_9H_6NO)_2{\cdot}2H_2O$ are formed. The hydrate $Cu(C_9H_6NO)_2{\cdot}2H_2O$ loses water when it is heated to 28 °C to give the anhydrous compound $Cu(C_9H_6NO)_2$.[19b] $Cu(C_9H_6NO)_2$ is a planar complex that can exist in both α and β forms. The α form consists of a chain of planar $Cu(C_9H_6NO)_2$ molecules, while the β form exists as a dimer-like unit.[19a] The pure α form undergoes a transformation into the β form when it is heated to 210 °C.[19b] Since the 8-hydroxyquinoline ligand can easily be exchanged for other ligands,[19b] these complexes, which are usually prepared in situ, are potential catalysts. In addition to the already mentioned *O*-arylations, a variety of other reactions, including *C*-vinylations of arylboronic acids,[19c] *N*-arylations of pyridine-2(1*H*)-ones,[19d] pyridazones[19e] and imidazoles,[19f] and the synthesis of methyl benzoates from benzyl alcohol and *tert*-butyl hydroperoxide,[19g] can be cat-

Table 2. Optimization of the reaction of *rac-syn*-**4a** using Cu^{II}/KI systems.[a]

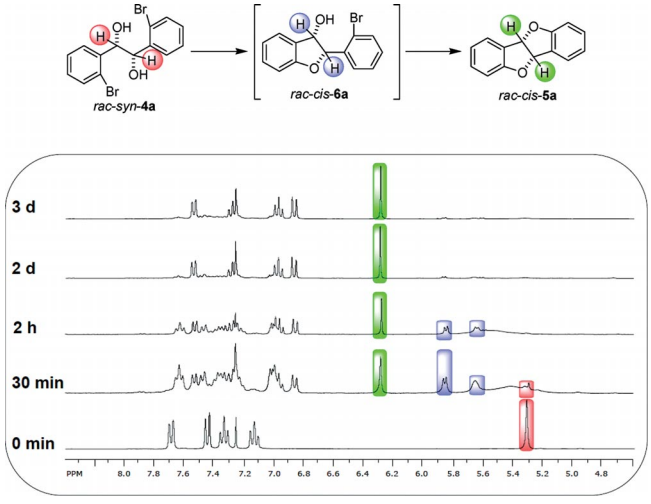


rac-syn-**4a** *rac-cis*-**5a**

Entry	Cu source (mol-%)	KI [equiv.]	Base (equiv.)	Solvent	Yield of *cis*-**5a** [%]
1	$CuSO_4$ (10)	4	K_3PO_4 (4)	CH_3CN/H_2O	81
2	$CuSO_4$ (10)	–	K_3PO_4 (4)	CH_3CN/H_2O	61
3	Cu^{II} oxinate (10)	4	K_3PO_4 (4)	CH_3CN/H_2O	93
4	Cu^{II} oxinate (10)	–	K_3PO_4 (4)	CH_3CN/H_2O	76
5	Cu^{II} oxinate (10)	4	K_2CO_3 (4)	CH_3CN/H_2O	51
6	Cu^{II} oxinate (10)	4	K_3PO_4 (4)	C_2H_5CN/H_2O	38
7	Cu^{II} oxinate (10)	4	K_3PO_4 (4)	tBuOH/H_2O	53
8	Cu^{II} oxinate (10)	4	K_3PO_4 (3)	CH_3CN/H_2O	69
9	Cu^{II} oxinate (10)	4	K_3PO_4 (2)	CH_3CN/H_2O	53
10	Cu^{II} oxinate (10)	4	K_3PO_4 (1)	CH_3CN/H_2O	16
11	Cu^{II} oxinate (10)	4	–	CH_3CN/H_2O	–[b]
12	Cu^{II} oxinate (10)	2	K_3PO_4 (4)	CH_3CN/H_2O	89
13	Cu^{II} oxinate (10)	1	K_3PO_4 (4)	CH_3CN/H_2O	90
14	Cu^{II} oxinate (10)	0.2	K_3PO_4 (4)	CH_3CN/H_2O	83
15	Cu^{II} oxinate (5)	4	K_3PO_4 (4)	CH_3CN/H_2O	66
16	–	4	K_3PO_4 (4)	CH_3CN/H_2O	–[c]

[a] In all cases, 0.5 mmol of *rac-syn*-**4a** was used. [b] *rac-syn*-**4a** was recovered in 82% yield. [c] *rac-syn*-**4a** was recovered in 87% yield.

alyzed by Cu^{II} oxinate or by using a copper source in the presence of 8-hydroxyquinoline as a ligand. With Cu^{II} oxinate (10 mol-%) and K_3PO_4 (4 equiv.) in a mixture of CH_3CN and H_2O (1:1 v/v), the cyclization product was isolated in 93% yield (Table 2, entry 3). Just as when $CuSO_4$ was used as the catalyst, the product was also formed in the absence of KI (Table 2, entry 4). It seems that the combination of CH_3CN and H_2O as a solvent system and K_3PO_4 as a base gives the best results (Table 2, entries 3 and 5–7). Finally, we studied whether the amounts of K_3PO_4, KI, and Cu^{II} oxinate could be decreased. Lowering the amount of K_3PO_4 from 4 to 3, 2, and 1 equiv. resulted in a marked decrease in the yields (Table 2, entries 8–10). Not surprisingly, the formation of *rac-cis*-**5a** was not observed at all in the absence of base (Table 2, entry 11). Under these conditions, *rac-syn*-**4a** was recovered in 82% yield. Our attempts to lower the amount of KI were met with more success. It turned out that the KI load could be decreased from 4 to 2 and 1 equiv., respectively, without any significant effect on the yields (Table 2, entries 12 and 13). Even when the reaction was run with as little as 20 mol-% KI, the yield of *rac-cis*-**5a** was 83% (Table 2, entry 14). Decreasing the amount of the copper catalyst was also tested. However, when the amount of Cu^{II} oxinate was decreased from 10 to 5 mol-%, the yield decreased by 27% (Table 2, entries 3 and 15). A control experiment confirmed that the reaction could not be run in the absence of a copper catalyst. In this case, only 87% of the starting material was isolated (Table 2, entry 16). To optimize the reaction time, the progress of the model reaction was followed by ^{1}H NMR spectroscopy (Scheme 4).



Scheme 4. Monitoring the progress of the transformation of *rac-syn*-**4a** into *rac-cis*-**5a** using ^{1}H NMR spectroscopy.

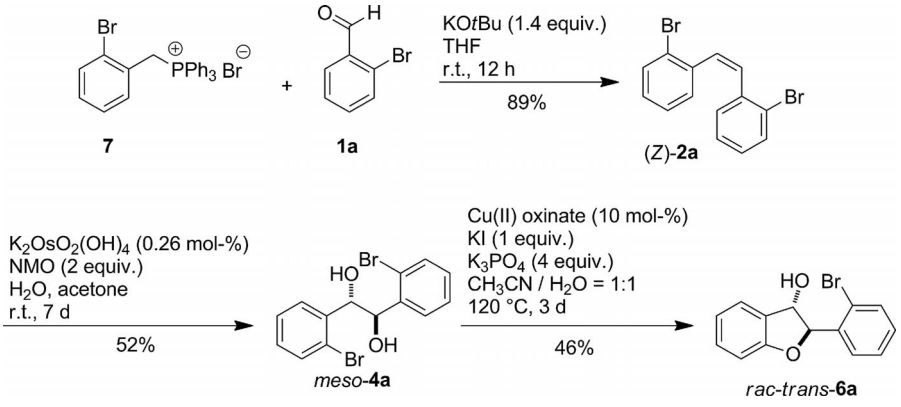
We assumed that the reaction proceeds in two discrete steps. The first step is the intramolecular cyclization of *rac-syn*-**4a** to 2-aryl-3-hydroxy-substituted *rac-cis*-**6a**.[20] This substance can then undergo intramolecular cyclization to deliver 4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-**5a**). As an indicator signal for the substrate, the singlet at δ = 5.3 ppm (which corresponds to the protons 1-H and 2-H of *rac-syn*-**4a**) was chosen (Scheme 4). The formation of intermediate *rac-cis*-**6a** was followed using the doublet at δ = 5.85 ppm, which was assigned to 2-H of **6a**. A characteristic signal for the product (i.e., *rac-cis*-**5a**) is the singlet res-

onating at δ = 6.3 ppm. It corresponds to the protons 4b-H and 9b-H.

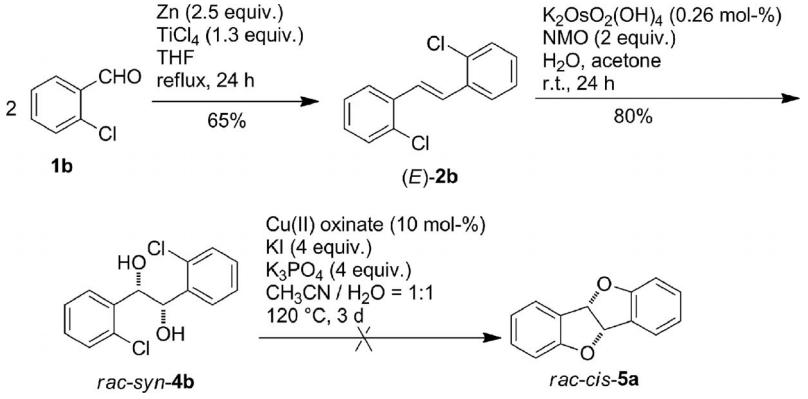
Analysis of the ^{1}H NMR spectra taken at the outset of the reaction (0 min), and after reaction times of 30 min, 2 h, 2 d, and 3 d clearly shows that after just 30 min a considerable amount of *rac*-*syn*-**4a** (ca. 80%) had been transformed into a ca. 1:2 mixture of *rac*-*cis*-**5a** and *rac*-*cis*-**6a**. It seems that after 2 h, most of the substrate (ca. 95%) had been consumed. At this time, the ratio of *rac*-*cis*-**5a** and *rac*-*cis*-**6a** was 1.2:1. The transformation of the remaining ca. 5% of substrate *rac*-*syn*-**4a** into *rac*-*cis*-**6a** and the further cyclization to *rac*-*cis*-**5a** proceeds remarkably slowly. Even after a reaction time of 2 d, traces of *rac*-*syn*-**4a** and *rac*-*cis*-**6a** could be detected. At this time, the ratio of *rac*-*cis*-**6a**:*rac*-*cis*-**5a** was ca. 1:20. Only after a reaction time of 3 d was the transformation of *rac*-*syn*-**4a** into *rac*-*cis*-**5a** complete. As a result, it turned out that the reaction time could not be decreased substantially.

Having established optimized reaction conditions (Table 2, entry 13), we studied whether the new reaction could also be used for the synthesis of enantiomerically pure 4b,9b-dihydrobenzofuro[3,2-*b*]benzofurans, i.e., whether the reaction of enantiomerically pure diol (+)-*syn*-**4a**[21a] exclusively delivers enantiomerically pure product (–)-*cis*-**5a**, or whether the transformation is accompanied by racemization. For this purpose, *rac*-*syn*-**4a** was subjected to the optimized reaction conditions, and the product (i.e., *rac*-*cis*-**5a**), obtained in 90% yield, was analyzed by chiral HPLC.[21b] The two enantiomers could be separated, and were found to be formed in a 1:1 ratio. HPLC analysis of the product resulting from the reaction of pure (+)-*syn*-**4a** revealed that (–)-*cis*-**5a** was formed exclusively. The enantiomeric product [i.e., (+)-*cis*-**5a**] was not detected at all. These results clearly demonstrate that the new method can be used for the synthesis of enantiomerically pure 4b,9b-dihydrobenzofuro[3,2-*b*]benzofurans. Next, the cyclization of the corresponding *anti* diol (i.e., *meso*-**4a**) was studied. Due to steric restraints, we expected this compound to only undergo intramolecular monoarylation. The required *anti* diol (i.e., *meso*-**4a**) was prepared by Wittig reaction between 2-bromobenzaldehyde (**1a**) and (2-bromobenzyl)triphenylphosphonium bromide (**7**) to give the diastereomerically pure (*Z*)-stilbene [i.e., (*Z*)-**2a**], and subsequent Upjohn dihydroxylation (Scheme 5). As expected, the reaction of *anti* 1,2-diol *meso*-**4a** with Cu^{II} oxinate (10 mol-%) in the presence of K_3PO_4 (4 equiv.) and KI (4 equiv.) at 120 °C for 3 d (conditions of Table 2 entry 3) exclusively delivered *trans*-2,3-disubstituted 2,3-dihydrobenzofuran *rac*-*trans*-**6a** as the product of an intramolecular monoarylation in 46% yield.

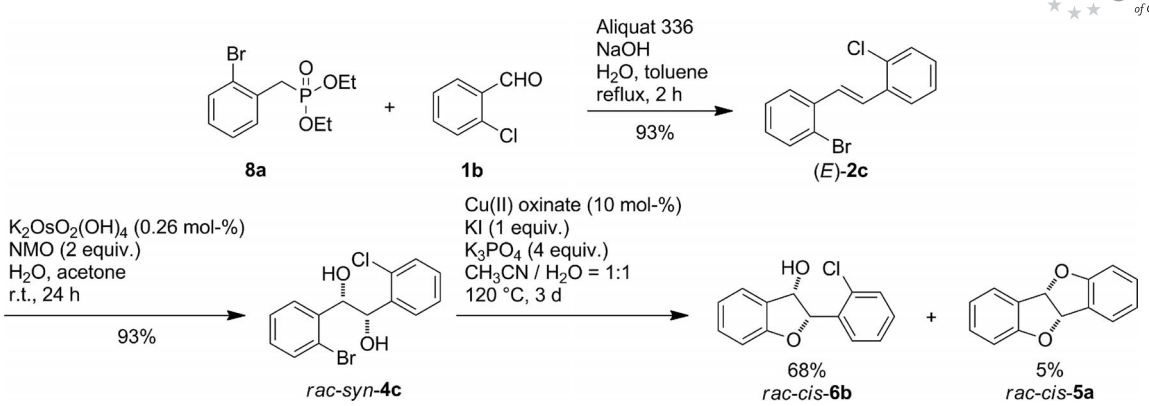
We wondered whether the reactivity of *rac*-*syn*-**4b**, i.e., the cyclization precursor with two chlorine atoms instead of two bromine atoms would be high enough to undergo intramolecular arylation(s). For this purpose, *rac*-*syn*-**4b** was prepared in 80% yield by dihydroxylation of (*E*)-**2b**,



Scheme 5. Synthesis of *anti* 1,2-diol *meso*-**4a** and its copper-catalyzed monoarylation t0 giveo *rac*-*trans*-**6a**.



Scheme 6. Synthesis of *rac*-*syn*-**4b** and its reaction under copper-catalyzed conditions.



Scheme 7. Synthesis of *rac-syn*-**4c** and its reaction under copper-catalyzed conditions.

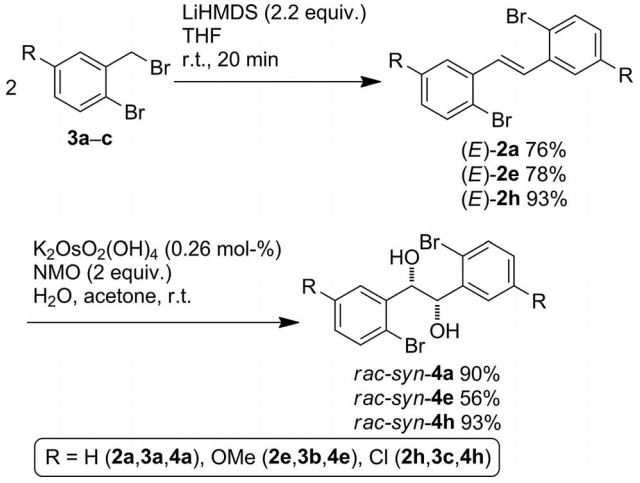
which in turn was obtained in 65% yield by McMurry coupling of **1b** (Scheme 6). It turned out that *rac-syn*-**4b** did not cyclize under the reaction conditions given in Table 2, entry 3.

Next, the "mixed" cyclization precursor *rac-syn*-1-(2-chlorophenyl)-2-(2-bromophenyl)ethane-1,2-diol (*rac-cis*-**4c**) was synthesized in 93% yield by dihydroxylation of (*E*)-**2c**, which was obtained by a Wittig–Horner reaction between 2-chlorobenzaldehyde (**1b**) and diethyl (2-bromophenyl)methylphosphonate (**8a**) in 93% yield (Scheme 7). Reaction of *rac-syn*-**4c** with Cu^{II} oxinate (10 mol-%) under the conditions of Table 2, entry 13 delivered the monoarylation product (i.e., *rac-cis*-**6b**) in 68% yield, and even 5% of the diarylation product (i.e., *rac-cis*-**5a**). This result not only confirms the higher reactivity of aryl bromides in comparison to aryl chlorides, but also demonstrates that our method can be used for the synthesis of *trans*-2,3-disubstituted 3-hydroxy-2,3-dihydrobenzofurans.

Finally, the scope of the new method for the synthesis of 4b,9b-dihydrobenzofuro[3,2-*b*]benzofurans was studied. For this purpose, a number of symmetrical and unsymmetrical (*E*)-stilbenes **2d**–**2i** were dihydroxylated to deliver the corresponding 1,2-diols [i.e., *rac-syn*-**4**(**d**–**i**)]. Symmetrically substituted (*E*)-stilbenes **2e** and **2h** were obtained by homocoupling of the corresponding *ortho*-bromobenzyl bromides (Scheme 8).

Unsymmetrically substituted (*E*)-stilbenes **2d**, **2f**, **2g**, and **2i** were prepared by Wittig–Horner olefination between *ortho*-bromobenzaldehydes **1a** or **1c** and diethylphosphonates **8a**–**8d** (Table 3).

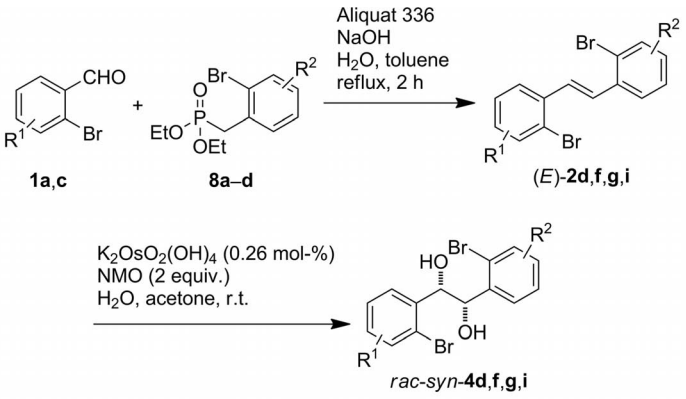
All of the 1,2-diols [i.e., *rac-syn*-**4**(**d**–**i**)] were subjected to the optimized reaction conditions established for the transformation of *rac-syn*-**4a** into *rac-cis*-**5a** (Table 2, entry 13). Irrespective of the substitution pattern of the substrates, the double intramolecular Ullmann reaction took place. In all cases, the *cis*-4b,9b-dihydrobenzofuro[3,2-*b*]benzofurans were formed exclusively with yields ranging between 55 and 90% (Table 4). The comparatively low yield for the transformation of *rac-syn*-**4f** into *rac-cis*-**5d** might be due to partial hydrolysis of the nitrile group under the reaction conditions. Thus, we have shown that the transformation tolerates a number of substituents, including fluoro, chloro, methoxy, and nitrile groups.

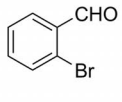
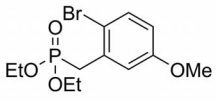
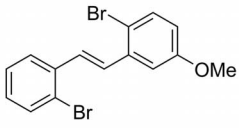
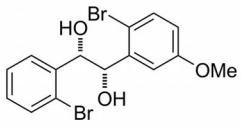
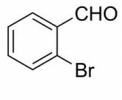
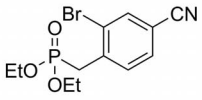
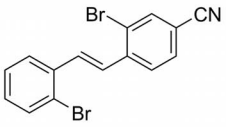
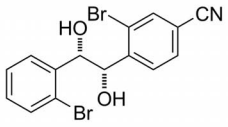
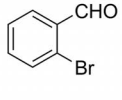
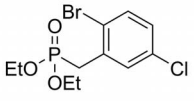
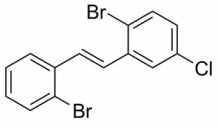
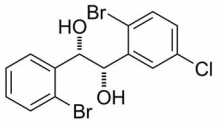
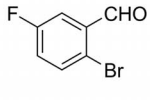
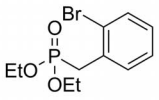
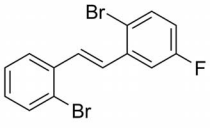
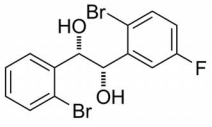


Scheme 8. Preparation of 1,2-diols *rac-syn*-**4**(**a**,**e**,**h**).

The structures of all of the substrates and products were unambiguously established by mass spectrometry and NMR spectroscopy, including 2D NMR spectroscopy for the full assignment of the ^1H and ^{13}C chemical shifts. As an example, the structure of (4b*RS*, 9b*RS*)-4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-**5a**) was unambiguously established by mass spectrometry and NMR spectroscopy. The signals were assigned by ^1H, ^{13}C, COSY, HSQC, and HMBC NMR spectroscopy (Figure 1). Since *rac-cis*-**5a** is a C_2-symmetric compound, its ^1H NMR spectrum shows only five signals: a singlet at δ = 6.29 ppm (4b-H and 9b-H), and a spin system consisting of two doublet-like multiplets at δ = 6.87 ppm (1-H and 6-H) and δ = 7.54 ppm (4-H and 9-H) and two triplet-like multiplets at δ = 6.97 ppm (3-H and 8-H) and δ = 7.28 ppm (2-H and 7-H). Analysis of the ^1H,^1H-COSY correlations reveal a typical ABCD spin system, consistent with a 1,2-disubstituted benzene derivative. The remarkably strong downfield shift of the signal representing the two chemically equivalent protons 4b-H and 9b-H can be rationalized as a combination of the diamagnetic aromatic ring current and the inductive effect of the oxygen atoms at positions 5 and 10. Due to the C_2 symmetry of *rac-cis*-**5a**, 4b-H and 9b-H are chemically equivalent and are represented by a singlet. For this reason it was impossible to directly determine the rela-

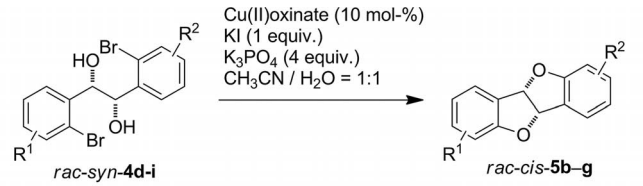
Table 3. Preparation of 1,2-diols *rac-syn*-**4**(**d**,**f**,**g**,**i**).

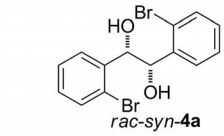
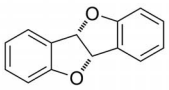
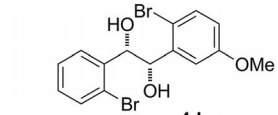
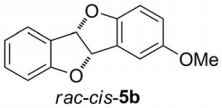
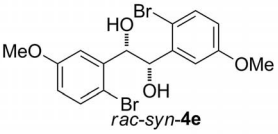
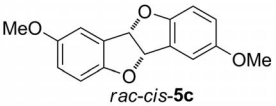
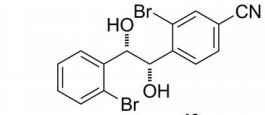
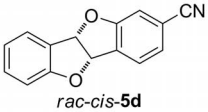
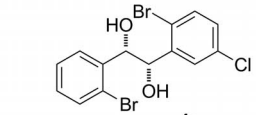
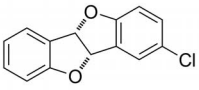
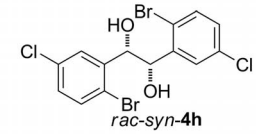
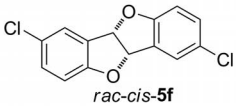
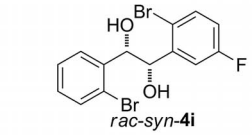
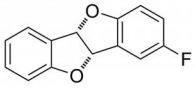


Entry	1	8	(*E*)-2	*rac-syn*-4
1	 **1a**	 **8b**	 (*E*)-**2d** (56%)	 *rac-syn*-**4d** (74%)
2	 **1a**	 **8c**	 (*E*)-**2f** (84%)	 *rac-syn*-**4f** (94%)
3	 **1a**	 **8d**	 (*E*)-**2g** (58%)	 *rac-syn*-**4g** (92%)
4	 **1c**	 **8a**	 (*E*)-**2i** (50%)	 *rac-syn*-**4i** (84%)

tive configuration based on the size of the vicinal coupling constant $^3J_{4b\text{-}H,9b\text{-}H}$. However, substitution of one of the ^{12}C carbon atoms at C-4b or C-9b by its ^{13}C isotop produces an ABX spin system (or an AA′X system if one ignores the very small ^1H chemical shift difference of A and A′ induced by the ^{13}C isotope shift). From the two doublets of doublets centered at δ = 6.29 ppm the outer one split by $^1J_{CH}$ = 162.9 Hz reveals the vicinal coupling constant ^3J(4b-H,9b-H) = 7.6 Hz. The inner doublet of doublets split by ^3J(4b-H, 9b-H) and $^2J_{CH}$ is overlapped by the strong ^1H (bonded to ^{12}C) resonance at δ = 6.29 ppm. The size of the vicinal coupling is typical for *cis*-3a,8b-furo[3,2-*b*]benzofurans and related heterocycles.[22] A comparison of the size of the vicinal coupling constants in *cis*- and *trans*-2,3-disubstituted 2,3-dihydrobenzofurans is of particular interest. For (2*RS*,3*RS*)-2-(2-bromophenyl)-2,3-dihydrobenzofuran-3-ol (*rac-cis*-**6a**), i.e., the intermediate of the copper-catalyzed double intramolecular *O*-arylation, $^3J_{2\text{-}H,3\text{-}H}$ has a value of 6.5 Hz, whereas for (2*RS*,3*SR*)-2-(2-bromophenyl)-2,3-dihydrobenzofuran-3-ol (*rac-trans*-**6a**) $^3J_{2\text{-}H,3\text{-}H}$ amounts to only 1.7 Hz. The observation that in the two 2-(2-bromophenyl)-2,3-dihydrobenzofuran-3-ols *rac-cis*-**6a** and *rac-trans*-**6a** $^3J_{cis\text{-}2,3}$ is significantly larger than $^3J_{trans\text{-}2,3}$ is corroborated by earlier reports.[22] In addition,

Table 4. Copper-catalyzed reactions of 1,2-diols *rac-syn*-**4(d–i)**.[a]



Entry	Substrate	Product	Yield of **5** [%]
1	 *rac-syn*-**4a**	 *rac-cis*-**5a**	90
2	 *rac-syn*-**4d**	 *rac-cis*-**5b**	64
3	 *rac-syn*-**4e**	 *rac-cis*-**5c**	82
4	 *rac-syn*-**4f**	 *rac-cis*-**5d**	55
5	 *rac-syn*-**4g**	 *rac-cis*-**5e**	81
6	 *rac-syn*-**4h**	 *rac-cis*-**5f**	77
7	 *rac-syn*-**4i**	 *rac-cis*-**5g**	81

[a] In all cases, 2 mmol of *rac-syn*-**4** was used.

the *cis* configuration of (2*RS*,3*RS*)-2-(2-chlorophenyl)-2,3-dihydrobenzofuran-3-ol (*rac-cis*-**6b**), which has a vicinal $^3J_{2\text{-}H,3\text{-}H}$ coupling constant of 6.5 Hz, was confirmed by the observation of a ROESY correlation between 2-H and 3-H. The *cis* configuration of *rac-cis*-**5e** was confirmed by computational studies. The calculations reported here were performed within density functional theory, using the Gaussian 03 package.[23] ^{1}H coupling constants were calculated for *rac-cis*-**5e** as follows: the rigid structures were optimized with the MM2 force field implemented in Chem3D Pro.[24] In the second step, the optimized structure was subsequently reoptimized at the AM1 level, followed by the RHF/3-21G level, and finally by the B3LYP/6-31G(d) level of theory within the Gaussian 03 package. In the final step, the gas-phase ^{1}H coupling constant was calculated at the mPW1PW91/6-311+G(2d,p)//mPW1PW91/6-31G(d) level of theory. These calculations gave a ^{1}H,^{1}H coupling constant of $^3J_{4b\text{-}H,9b\text{-}H}$ = 7.9 Hz. The calculated value is in good agreement with the observed coupling constant of $^3J_{4b\text{-}H,9b\text{-}H}$ = 7.5 Hz.

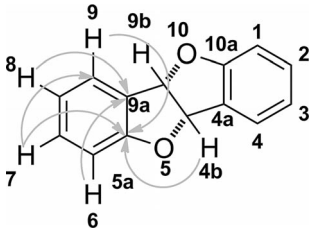


Figure 1. Important HMBC correlations of *rac-cis*-**5a**.

Conclusions

In summary, we present a copper-catalyzed double intramolecular *O*-arylation of substituted *syn*-1,2-bis(2-bromoaryl)ethane-1,2-diols to give the corresponding 4b,9b-dihydrobenzofuro[3,2-*b*]benzofurans in diastereomerically and enantiomerically pure form. Using Cu^{II} oxinate as the catalyst, K_3PO_4 as the base, KI as a reductant, and acetonitrile/water as the reaction medium, the method gives yields of up to 90%. The substrates are readily available in racemic and enantiomerically pure form using established synthetic methods. The use of an enantiomerically pure *syn*-1,2-bis(2-bromoaryl)ethane-1,2-diol as substrate resulted in the formation of a single enantiomer of the product, as verified by chiral HPLC. The transformation tolerates several substituents, including fluoro, chloro, methoxy, and nitrile groups. Monitoring the reaction by ^{1}H NMR spectroscopy confirmed that it can be considered as a double intramolecular *O*-arylation with a 2-(2-bromoaryl)-2,3-dihydrobenzofuran-3-ol as an intermediate. With an *anti*-1,2-bis(2-bromoaryl)ethane-1,2-diol as substrate, the double intramolecular *O*-arylation does not occur. Instead, the monoarylation product is formed exclusively in diastereomerically pure form.

Experimental Section

General Remarks: Acetonitrile and solvents used for extraction and purification were distilled prior to use. Tetrahydrofuran was dried using sodium/benzophenone. All reagents were used without further purification. Reaction temperatures are reported as bath temperatures. Thin-layer chromatography (TLC) was carried out on aluminum-backed plates coated with silica gel with F254 indicator (Merck). Compounds were visualized with UV light (λ = 254 nm), and by immersion in a $KMnO_4$ solution or in an ethanolic vanillin solution, followed by heating. Products were purified by flash chromatography on silica gel, 0.04–0.063 mm mesh (Macherey–Na-

gel & Co), or by crystallization. Melting points were recorded with a Büchi B-545 melting-point apparatus with open capillary tubes. IR spectra were measured with a Bruker Alfa FTIR spectrometer. UV/Vis spectra were recorded with a Varian Cary 50 instrument. ^{1}H and ^{13}C NMR spectra were recorded at 500/125 or 300/75 MHz using Varian Unity Inova spectrometers, with $CDCl_3$ as the solvent. The ^{1}H and ^{13}C chemical shifts were referenced to residual solvent signals at $\delta_{H/C}$ = 7.26/77.00 ppm ($CDCl_3$). HSQC, HMBC, and COSY spectra were recorded with Varian Unity Inova spectrometers at 300 and 500 MHz. Coupling constants *J* [Hz] were directly taken from the spectra, and are not averaged. Splitting patterns are designated as s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), and br (broad). 1D and 2D homonuclear NMR spectra were measured with standard pulse sequences. Copies of the NMR spectra were prepared using SpinWorks.[25] Low-resolution electron-impact mass spectra [MS (EI)] and exact-mass electron-impact mass spectra [HRMS (EI)] were obtained at 70 eV using a double-focusing sector-field mass spectrometer (Finnigan MAT 95). Low-resolution electrospray-ionization mass spectra [MS (ESI)] and exact-mass electrospray-ionization mass spectra [HRMS (ESI)] were obtained using a Bruker Daltonics (micro TOFQ) instrument. Intensities are reported as percentages relative to the base peak (*I* = 100%).

General Procedure I for the Preparation of Symmetrical Stilbenes 2 from Benzyl Bromides 3:[13b] The benzyl bromide **3** (20 mmol) was placed in a Schlenk flask under argon. LiHMDS solution (1 M in tetrahydrofuran; 44 mL) was added dropwise with stirring at 0 °C. After the addition was complete, the reaction mixture was stirred for 20 min at 0 °C. Saturated aqueous NH_4Cl solution (20 mL) was then added, and the mixture was extracted with *tert*-butylmethyl ether (3 × 30 mL). The combined organic layers were washed with saturated aqueous NH_4Cl solution (30 mL), and water (30 mL), and dried with Na_2SO_4. The solvent was removed under reduced pressure. The resulting residue was dissolved in dichloromethane (50 mL), the solution was filtered through silica gel, and the product was crystallized from methanol to give the stilbene **2**.

General Procedure II for the Preparation of Unsymmetrical Stilbenes 2 from 2-Bromobenzaldehydes 1 and Benzylphosphonates 8:[14] Aliquat 336 (1.5 mL) was added to a stirred mixture of toluene (20 mL) and aqueous NaOH (50%; 20 mL). A solution of the 2-bromobenzaldehyde **1** (25 mmol) and the benzylphosphonate **8** (25 mmol) in toluene (10 mL) was added dropwise at 25 °C. The mixture was heated at reflux for 30 min. The mixture was then cooled to room temperature, and the aqueous layer was separated and extracted with toluene (2 × 30 mL). The combined organic layers were washed with saturated aqueous NH_4Cl (30 mL), and brine (2 × 30 mL). The solvent was removed under reduced pressure. The resulting residue was dissolved in dichloromethane (100 mL), and the solution was filtered through silica gel. Evaporation of the solvent, followed by crystallization of the crude product from methanol delivered the stilbene **2**.

(*E*)-1,2-Bis(2-bromophenyl)ethene [(*E*)-2a]:[26] 2-Bromobenzyl bromide (**3a**; 5.02 g, 20 mmol) was used according to general procedure I. Crystallization from methanol gave (*E*)-1,2-bis(2-bromophenyl)ethene [(*E*)-**2a**] (2.56 g, 7.57 mmol, 76%) as a colorless solid. R_f = 0.30 (petroleum ether), m.p. 110–111 °C (ref.[26] m.p. 108–108.5 °C). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.15 (ddd, ^3J = 8.0, ^3J = 7.3 Hz, ^4J = 1.7 Hz, 2 H), 7.34 (ddd, 2 × $^3J \approx$ 7.5, ^4J = 1.3 Hz, 2 H), 7.41 (s, 2 H), 7.60 (dd, ^3J = 7.6, ^4J = 1.3 Hz, 2 H) 7.73 (dd, ^3J = 7.9, ^4J = 1.7 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 124.2, 127.2, 127.7, 129.2, 130.1, 133.1, 136.8 ppm. MS (EI): *m*/*z* (%) = 336 (11) $[M]^+$, 178 (100).

(*Z*)-1,2-Bis(2-bromophenyl)ethene [(*Z*)-2a]:[26] A solution of KO*t*Bu (1.34 g, 14 mmol) in tetrahydrofuran (40 mL) was added portionwise to a stirred solution of 2-bromobenzyltriphenylphosphonium bromide (**7**; 5.17 g, 10.1 mmol) in tetrahydrofuran (160 mL) under argon at 25 °C. The mixture was stirred for 5 min, then 2-bromobenzaldehyde (**1a**; 2.44 g, 13.2 mmol) was added dropwise at 25 °C. The reaction mixture was stirred overnight at 25 °C, then it was filtered through silica gel, and the solvent was removed under reduced pressure. Flash chromatography of the crude product over silica gel (petroleum ether) gave (*Z*)-1,2-bis(2-bromophenyl)ethene [(*Z*)-**2a**] (3.04 g, 8.99 mmol, 89%) as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.79 (s, 2 H, 1-H and 2-H), 6.91–7.09 (m, 6 H), 7.57 (dd, ^3J = 7.0, ^4J = 2.1 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 124.0, 126.9, 128.8, 130.9, 132.6, 137.0 ppm. MS (EI): *m*/*z* (%) = 336 (12), 178 (100).

Synthesis of (*E*)-1,2-Bis(2-chlorophenyl)ethene [(*E*)-2b] by McMurry Coupling of 2-Chlorobenzaldehyde (1b)

(*E*)-1,2-Bis(2-chlorophenyl)ethene [(*E*)-2b]:[27] $TiCl_4$ (24.7 g, 130 mmol) was added dropwise to an ice-cooled mixture of Zn (16.4 g, 250 mmol) and dry THF (150 mL). Then, 2-chlorobenzaldehyde (**1b**; 140.7 g, 100 mmol) was added dropwise. The mixture was heated at reflux for 24 h. The mixture was then cooled to room temperature, and filtered, and the solvent was evaporated under reduced pressure. The resulting residue was dissolved in CH_2Cl_2 (30 mL), the solution was filtered through silica gel, and the solvent was evaporated under reduced pressure. Crystallization of the crude product from petroleum ether gave (*E*)-1,2-bis(2-chlorophenyl)ethene [(*E*)-**2b**] (8.12 g, 32.6 mmol, 65%), m.p. 95–96 °C (ref.[27] m.p. 96–97 °C). R_f = 0.28 (petroleum ether). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.23 (ddd, 2 × $^3J \approx$ 7.5, ^4J = 1.8 Hz, 2 H), 7.30 (ddd, 2 × $^3J \approx$ 7.5, ^4J = 1.5 Hz, 2 H), 7.40 (dd, ^3J = 7.8, ^4J = 1.6 Hz, 2 H), 7.50 (s, 2 H), 7.75 (dd, ^3J = 7.7, ^4J = 1.8 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 126.9, 127.0, 127.3, 128.9, 129.8, 133.6, 135.2 ppm. MS (EI): *m*/*z* (%) = 248 (33) $[M]^+$, 213 (21), 178 (100), 151 (10), 88 (11).

(*E*)-1-(2-Bromostyryl)-2-chlorobenzene [(*E*)-2c]: 2-Chlorobenzaldehyde (**1b**; 1.41 g, 10 mmol) and diethyl (2-bromophenyl)methylphosphonate (**8a**; 3.07 g, 10 mmol) were used according to general procedure II. Crystallization from methanol gave (*E*)-1-(2-bromostyryl)-2-chlorobenzene [(*E*)-**2c**] (2.73 g, 9.3 mmol, 93%) as a colorless solid. R_f = 0.62 (petroleum ether), m.p. 89–90 °C. IR: $\tilde{\nu}$ = 3051, 1586, 1561, 1472, 1436, 1324, 1276, 1252, 1216, 1156, 1123, 1139, 1017, 956, 855, 750, 719, 663, 557, 543 cm^{-1}. UV (CH_3CN): λ_{max} (logε) = 293 (4.32), 230 (4.17), 209 (4.38) nm. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.15 (ddd, 2 × $^3J \approx$ 7.7, $^4J_{4'\text{-H},6'\text{-H}}$ = 1.7 Hz, 1 H, 4′-H), 7.23 (ddd, 2 × $^3J \approx$ 7.8, $^4J_{4''\text{-H},6''\text{-H}}$ = 1.7 Hz, 1 H, 4′-H), 7.30 (ddd, 2 × $^3J \approx$ 7.5, $^4J_{5''\text{-H},3''\text{-H}}$ = 1.4 Hz, 1 H, 5′-H), 7.34 (ddd, 2 × $^3J \approx$ 7.5, $^4J_{5'\text{-H},3'\text{-H}}$ = 1.3 Hz, 1 H, 5′-H), 7.40 (dd, $^3J_{3''\text{-H},4''\text{-H}}$ = 7.9, $^4J_{3''\text{-H},5''\text{-H}}$ = 1.4 Hz, 1 H, 3′′-H), 7.45 (s, 2 H, 1-H and 2-H), 7.60 (dd, $^3J_{3'\text{-H},4'\text{-H}}$ = 8.0, $^4J_{3'\text{-H},5'\text{-H}}$ = 1.3 Hz, 1 H, 3′-H), 7.71–7.77 (m, 2 H, 6′-H and 6′′-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 124.3 (C-2′), 126.9 (C-6′′), 127.0 (C-5′′), 127.1 (C-6′), 127.5 (C-1 or C-2), 127.6 (C-5′), 129.0 (C-4′′), 129.2 (C-4′), 129.8 (C-3′′), 129.9 (C-1 or C-2), 133.1 (C-3′), 133.6 (C-2′′), 135.1 (C-1′′), 136.9 (C-1′) ppm. MS (EI): *m*/*z* (%) = 292 (33) $[M]^+$, 213 (7), 178 (100), 151 (6), 88 (7). HRMS (EI): calcd. for $C_{14}H_{10}BrCl$ $[M]^+$ 291.9654; found 291.9653.

(*E*)-2-(2-Bromostyryl)-1-bromo-4-methoxybenzene [(*E*)-2d]: 2-Bromobenzaldehyde (**1a**; 4.63 g, 25 mmol) and diethyl (2-bromo-5-methoxyphenyl)methylphosphonate (**8b**; 9.30 g, 25 mmol) were used according to general procedure II. Crystallization from methanol gave (*E*)-2-(2-bromostyryl)-1-bromo-4-methoxybenzene [(*E*)-

2d] (5.19 g, 14.1 mmol, 56%) as a colorless solid. R_f = 0.24 (petroleum ether), m.p. 90–91 °C. IR: $\tilde{\nu}$ = 2969, 1585, 1460, 1432, 1404, 1331, 1289, 1248, 1229, 1210, 1172, 1113, 1041, 1013, 953, 938, 859, 830, 815, 801, 757, 736, 714, 671, 631, 608, 559, 522, 497, 483, 452, 402 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 291 (4.30), 231 (4.27), 222 (4.28) nm. ^1H NMR (500 MHz, $CDCl_3$): δ = 3.86 (s, 3 H, OCH_3), 6.70 (dd, $^3J_{4'\text{-H},3'\text{-H}}$ = 8.8, $^4J_{4'\text{-H},6'\text{-H}}$ = 3.1 Hz, 1 H, 4′-H), 7.15 (ddd, $^3J_{4''\text{-H},3''\text{-H}}$ = 8.0, $^3J_{4''\text{-H},5''\text{-H}}$ = 7.3 Hz, $^4J_{4''\text{-H},6''\text{-H}}$ = 1.7 Hz, 1 H, 4′′-H), 7.24 (d, $^4J_{6'\text{-H},4'\text{-H}}$ = 3.0 Hz, 1 H, 6′-H), 7.34 (ddd, $^3J_{5''\text{-H},4''\text{-H}} \approx 7.5$, $^3J_{5''\text{-H},6''\text{-H}} \approx 7.5$ Hz, $^4J_{5''\text{-H},3''\text{-H}}$ = 1.4 Hz, 1 H, 5′′-H), 7.34 (d, $^3J_{1\text{-H},2\text{-H}}$ or $^3J_{2\text{-H},1\text{-H}}$ = 16.1 Hz, 1 H, 1-H or 2-H), 7.39 (d, $^3J_{1\text{-H},2\text{-H}}$ or $^3J_{2\text{-H},1\text{-H}}$ = 16.1 Hz, 1 H, 1-H or 2-H), 7.48 (d, $^3J_{3'\text{-H},4'\text{-H}}$ = 8.8 Hz, 1 H, 3′-H), 7.59 (dd, $^3J_{3''\text{-H},4''\text{-H}}$ = 8.0, $^4J_{3''\text{-H},5''\text{-H}}$ = 1.3 Hz, 1 H, 3′′-H), 7.72 (dd, $^3J_{6''\text{-H},5''\text{-H}}$ = 7.8, $^4J_{6''\text{-H},4''\text{-H}}$ = 1.7 Hz, 1 H, 6′′-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 55.6 (OCH_3), 112.4 (C-6′), 115.0 (C-2′), 115.3 (C-4′), 124.3 (C-2′′), 127.2 (C-6′′), 127.7 (C-5′′), 129.3 (C-4′′), 130.19 (C-1 or C-2), 130.20 (C-1 or C-2), 133.1 (C-3′′), 133.6 (C-3′), 136.7 (C-1′′), 137.5 (C-1′), 159.1 (C-5′) ppm. MS (EI): *m*/*z* (%) = 366 (34) $[M]^+$, 208 (100), 193 (45), 163 (46), 139 (14), 104 (31). HRMS (EI): calcd. for $C_{15}H_{12}Br_2O$ $[M]^+$ 365.9249; found 365.9246.

(*E*)-1,2-Bis(2-bromo-5-methoxyphenyl)ethene [(*E*)-2e]:[28] 1-Bromo-2-(bromomethyl)-4-methoxybenzene (**3b**; 5.64 g, 20.2 mmol) was used according to general procedure I. Crystallization of the crude product from methanol gave (*E*)-1,2-bis(2-bromo-5-methoxyphenyl)ethene [(*E*)-**2e**] (3.12 g, 7.84 mmol, 78%) as a colorless solid. R_f = 0.15 (petroleum ether), m.p. 152–154 °C (ref.[28] m.p. 154–155 °C). IR: $\tilde{\nu}$ = 2926, 2837, 1872, 1588, 1572, 1458, 1407, 1340, 1285, 1247, 1229, 1203, 1168, 1116, 1042, 1012, 952, 865, 841, 798, 729, 707, 617, 565, 499, 467, 454, 395 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 3.85 (s, 6 H, OCH_3), 6.75 (dd, $^3J_{4'\text{-H},3'\text{-H}}$ = $^3J_{4''\text{-H},3''\text{-H}}$ = 8.8, $^4J_{4'\text{-H},6'\text{-H}}$ = $^4J_{4''\text{-H},6''\text{-H}}$ = 3.0 Hz, 2 H, 4′-H and 4′′-H), 7.23 (d, $^4J_{6'\text{-H},4'\text{-H}}$ = $^4J_{6''\text{-H},4''\text{-H}}$ = 3.0 Hz, 2 H, 6′-H and 6′′-H), 7.33 (s, 2 H, 1-H and 2-H), 7.47 (d, $^3J_{3'\text{-H},4'\text{-H}}$ = $^3J_{3''\text{-H},4''\text{-H}}$ = 8.8 Hz, 2 H, 3′-H and 3′′-H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 55.6 (OCH_3), 112.4 (C-6′ and C-6′′), 115.0 (C-2′ and C-2′′), 115.4 (C-4′ and C-4′′), 130.3 (C-1 and C-2), 133.6 (C-3′ and C-3′′), 137.4 (C-1′ and C-1′′), 159.1 (C-5′ and C-5′′) ppm. MS (EI): *m*/*z* (%) = 396 (5) $[M]^+$, 317 (5), 238 (100), 223 (36), 208 (2), 195 (18), 180 (5), 152 (11).

(*E*)-4-(2-Bromostyryl)-3-bromobenzonitrile [(*E*)-2f]: 2-Bromobenzaldehyde (**1a**; 1.85 g, 10 mmol) and diethyl (2-bromo-4-cyanophenyl)methylphosphonate (**8c**; 3.33 g, 10 mmol) were used according to general procedure II. Crystallization from methanol gave (*E*)-4-(2-bromostyryl)-3-bromobenzonitrile [(*E*)-**2f**] (3.05 g, 8.4 mmol, 84%) as a colorless solid. R_f = 0.56 (petroleum ether/dichloromethane, 7:3), m.p. 156–158 °C. IR: $\tilde{\nu}$ = 3062, 2225, 1736, 1593, 1478, 1433, 1387, 1326, 1271, 1225, 1191, 1041, 1022, 954, 904, 888, 845, 821, 785, 754, 738, 666, 591, 564, 460, 443 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 312 (4.27), 239 (4.12), 210 (4.41) nm. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.20 (ddd, $^3J_{4''\text{-H},3''\text{-H}} \approx 7.9$, $^3J_{4''\text{-H},5''\text{-H}} \approx 7.9$ Hz, $^4J_{4''\text{-H},6''\text{-H}}$ = 1.7 Hz, 1 H, 4′′-H), 7.36 (ddd, $^3J_{5''\text{-H},4''\text{-H}} \approx 7.3$, $^3J_{5''\text{-H},6''\text{-H}} \approx 7.3$ Hz, $^4J_{5''\text{-H},3''\text{-H}}$ = 1.2 Hz, 1 H, 5′′-H), 7.46 (d, $^3J_{1\text{-H},2\text{-H}}$ = 16.2 Hz, 1 H, 1-H), 7.52 (d, $^3J_{2\text{-H},1\text{-H}}$ = 16.1 Hz, 1 H, 2-H), 7.61 (ddd, $^3J_{5'\text{-H},6'\text{-H}}$ = 8.2, $^4J_{5'\text{-H},3'\text{-H}}$ = 1.7 Hz, J = 0.6 Hz, 1 H, 5′-H), 7.62 (dd, $^3J_{3''\text{-H},4''\text{-H}}$ = 8.0, $^4J_{3''\text{-H},5''\text{-H}}$ = 1.3 Hz, 1 H, 3′′-H), 7.72 (dd, $^3J_{6''\text{-H},5''\text{-H}}$ = 7.9, $^4J_{6''\text{-H},4''\text{-H}}$ = 1.7 Hz, 1 H, 6′′-H), 7.80 (d, $^3J_{6'\text{-H},5'\text{-H}}$ = 8.2 Hz, 1 H, 6′-H), 7.88 (d, $^3J_{3'\text{-H},5'\text{-H}}$ = 1.7 Hz, 1 H, 3′-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 112.4 (C-4′), 117.4 (CN), 124.1 (C-2′), 124.6 (C-2′′), 127.3 (overlapped, C-6′), 127.3 (overlapped, C-6′′), 127.8 (C-5′′), 128.4 (C-1), 130.1 (C-5′), 131.0 (C-4′′), 133.3 (C-3′′), 133.4 (C-2), 135.9 (C-1′′), 136.4 (C-3′), 141.5 (C-1′) ppm. MS (EI): *m*/*z* (%) = 361 (35) $[M]^+$, 283 (4), 203 (100), 175 (30), 150 (10), 101.5 (67), 88 (76), 75 (21). HRMS (EI): calcd. for $[C_{15}H_9Br_2N]^+$ 360.9096; found 360.9099.

(*E*)-2-(2-Bromostyryl)-1-bromo-4-chlorobenzene [(*E*)-2g]: 2-Bromobenzaldehyde (**1a**; 4.65 g, 25 mmol) and diethyl (2-bromo-5-chlorophenyl)methylphosphonate (**8d**; 8.55 g, 25 mmol) were used according to general procedure II. Crystallization from methanol gave (*E*)-2-(2-bromostyryl)-1-bromo-4-chlorobenzene [(*E*)-**2g**] (5.44 g, 14.6 mmol, 58%) as a colorless solid. R_f = 0.55 (petroleum ether), m.p. 89–91 °C. IR: $\tilde{\nu}$ = 3055, 1792, 1575, 1467, 1436, 1394, 1322, 1240, 1215, 1190, 1096, 1046, 1022, 956, 913, 872, 838, 805, 748, 713, 667, 558, 541, 509, 466, 449 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 291 (4.32), 214 (4.39) nm. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.13 (dd, $^3J_{4'\text{-H},3'\text{-H}}$ = 8.6, $^4J_{4'\text{-H},6'\text{-H}}$ = 2.5 Hz, 1 H, 4′-H), 7.17 (ddd, $^3J_{4''\text{-H},3''\text{-H}}$ = 7.9, $^3J_{4''\text{-H},5''\text{-H}}$ = 7.5 Hz, $^4J_{4''\text{-H},6''\text{-H}}$ = 1.7 Hz, 1 H, 4′′-H), 7.30 (d, $^3J_{1\text{-H},2\text{-H}}$ = 16.1 Hz, 1 H, 1-H), 7.34 (ddd, $^3J_{5''\text{-H},4''\text{-H}} \approx 7.8$, $^3J_{5''\text{-H},6''\text{-H}} \approx 7.8$ Hz, $^4J_{5''\text{-H},3''\text{-H}}$ = 1.4 Hz, 1 H, 5′′-H), 7.39 (d, $^3J_{2\text{-H},1\text{-H}}$ = 16.1 Hz, 1 H, 2-H), 7.51 (d, $^3J_{3'\text{-H},4'\text{-H}}$ = 8.5 Hz, 1 H, 3′-H), 7.60 (dd, $^3J_{3''\text{-H},4''\text{-H}}$ = 7.8, $^4J_{3''\text{-H},5''\text{-H}}$ = 1.7 Hz, 1 H, 3′′-H), 7.67 (d, $^4J_{6'\text{-H},4'\text{-H}}$ = 2.5 Hz, 1 H, 6′-H), 7.70 (dd, $^3J_{6''\text{-H},5''\text{-H}}$ = 7.8, $^4J_{6''\text{-H},4''\text{-H}}$ = 1.7 Hz, 1 H, 6′′-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 121.9 (C-2′), 124.4 (C-2′′), 126.6 (6′), 127.2 (C-6′′), 127.7 (C-5′′), 129.0 (C-1), 129.1 (C-4′), 129.6 (C-4′′), 131.1 (C-2), 133.2 (C-3′′), 133.8 (C-5′), 134.1 (C-3′), 136.4 (C-1′′), 138.3 (C-1′) ppm. MS (EI): *m*/*z* (%) = 370 (29) $[M]^+$, 292 (7), 256 (11), 212 (100), 177 (66), 150 (25), 106 (71), 75 (29). HRMS (EI): calcd. for $[C_{14}H_9Br_2Cl]^+$ 369.8754; found 369.8760.

(*E*)-1,2-Bis(2-bromo-5-chlorophenyl)ethene [(*E*)-2h]: 1-Bromo-2-(bromomethyl)-4-chlorobenzene (**3c**; 5.70 g, 20 mmol) was used according to general procedure I. Crystallization of the crude product from methanol gave (*E*)-1,2-bis(2-bromo-5-chlorophenyl)ethene [(*E*)-**2h**] (3.47 g, 8.53 mmol, 85%) as a colorless solid. R_f = 0.50 (petroleum ether), m.p. 184–185 °C. IR: $\tilde{\nu}$ = 3054, 1736, 1574, 1548, 1454, 1394, 1317, 1264, 1237, 1209, 1092, 1023, 957, 897, 868, 815, 695, 584, 553, 448 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 288 (3.91), 218 (4.07) nm. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.14 (dd, $^3J_{4'\text{-H},3'\text{-H}}$ = $^3J_{4''\text{-H},3''\text{-H}}$ = 8.6, $^4J_{4'\text{-H},6'\text{-H}}$ = $^4J_{4''\text{-H},6''\text{-H}}$ = 2.5 Hz, 2 H, 4′-H and 4′′-H), 7.29 (s, 2 H, 1-H and 2-H), 7.52 (d, $^3J_{3'\text{-H},4'\text{-H}}$ = $^3J_{3''\text{-H},4''\text{-H}}$ = 8.5 Hz, 2 H, 3′-H and 3′′-H), 7.65 (d, $^4J_{6'\text{-H},4'\text{-H}}$ = $^4J_{6''\text{-H},4''\text{-H}}$ = 2.4 Hz, 2 H, 6′-H and 6′′-H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 122.1 (C-2′ and C-2′′), 127.0 (C-6′ and C-6′′), 129.4 (C-4′ and C-4′′), 130.1 (C-1 and C-2), 133.8 (C-5′ and C-5′′), 134.2 (C-3′ and C-3′′), 137.9 (C-1′ and C-1′′) ppm. MS (EI): *m*/*z* (%) = 404 (5) $[M]^+$, 278 (25), 246 (100), 210 (16), 176 (32), 138 (7). HRMS (EI): calcd. for $C_{14}H_8Br_2Cl_2$ $[M]^+$ 403.8364; found 403.8369.

(*E*)-2-(2-Bromostyryl)-1-bromo-4-fluorobenzene [(*E*)-2i]: 2-Bromo-5-fluorobenzaldehyde (**1c**; 5.09 g, 25 mmol) and diethyl (2-bromophenyl)methylphosphonate (**8a**; 7.68 g, 25 mmol) were used according to general procedure II. Crystallization from methanol gave (*E*)-2-(2-bromostyryl)-1-bromo-4-fluorobenzene [(*E*)-**2i**] (4.49 g, 12.6 mmol, 50%) as a colorless solid. R_f = 0.55 (petroleum ether), m.p. 87–89 °C. IR: $\tilde{\nu}$ = 3053, 1793, 1573, 1464, 1409, 1326, 1268, 1249, 1202, 1158, 1100, 1049, 1022, 975, 953, 875, 798, 741, 712, 672, 630, 592, 557, 511, 451, 397 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 291 (4.28), 232 (4.16) nm. ^1H NMR (500 MHz, $CDCl_3$): δ = 6.90 (ddd, $^3J_{4'\text{-H},5'\text{-F}}$ = 8.8, $^3J_{4'\text{-H},3'\text{-H}}$ = 7.8 Hz, $^4J_{4'\text{-H},6'\text{-H}}$ = 3.0 Hz, 1 H, 4′-H), 7.17 (ddd, $^3J_{4''\text{-H},3''\text{-H}}$ = 7.9, $^3J_{4''\text{-H},5''\text{-H}}$ = 7.5 Hz, $^4J_{4''\text{-H},6''\text{-H}}$ = 1.7 Hz, 1 H, 4′′-H), 7.33 (d, $^3J_{1\text{-H},2\text{-H}}$ = 16.2 Hz, 1 H, 1-H), 7.34 (ddd, $^3J_{5''\text{-H},4''\text{-H}} \approx 7.6$, $^3J_{5''\text{-H},6''\text{-H}} \approx 7.6$ Hz, $^4J_{5''\text{-H},3''\text{-H}}$ = 1.3 Hz, 1 H, 5′′-H), 7.40 (d, $^3J_{2\text{-H},1\text{-H}}$ = 16.1 Hz, 1 H, 2-H), 7.43

(dd, $^3J_{6'\text{-H},5'\text{-F}}$ = 9.7, $^4J_{6'\text{-H},4'\text{-H}}$ = 3.0 Hz, 1 H, 6′-H), 7.54 (dd, $^3J_{3'\text{-H},4'\text{-H}}$ = 8.8, $^4J_{3'\text{-H},5'\text{-F}}$ = 5.3 Hz, 1 H, 3′-H), 7.60 (dd, $^3J_{3''\text{-H},4''\text{-H}}$ = 8.0, $^4J_{3''\text{-H},5''\text{-H}}$ = 1.3 Hz, 1 H, 3′′-H), 7.71 (dd, $^3J_{6''\text{-H},5''\text{-H}}$ = 7.8, $^4J_{6''\text{-H},4''\text{-H}}$ = 1.7 Hz, 1 H, 6′′-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 113.7 (d, $J_{C,F}$ = 23.5 Hz, C-6′), 116.4 (d, $J_{C,F}$ = 22.9 Hz, C-4′), 118.3 (d, $J_{C,F}$ = 3.0 Hz, C-2′), 124.4 (C-2′′), 127.2 (C-6′′), 127.7 (C-5′′), 129.2 (d, $J_{C,F}$ = 2.3 Hz, C-2), 129.6 (C-4′′), 131.2 (d, $J_{C,F}$ = 0.8 Hz, C-1), 133.2 (C-3′′), 134.2 (d, $J_{C,F}$ = 8.1 Hz, C-3′), 136.4 (C-1′′), 138.5 (d, $J_{C,F}$ = 7.8 Hz, C-1′), 162.1 (d, $J_{C,F}$ = 247.1 Hz, C-5′) ppm. MS (EI): *m*/*z* (%) = 354 (31) $[M]^+$, 276 (4), 196 (100), 175 (19), 98 (52), 85 (17), 75 (7). HRMS (EI): calcd. for $C_{14}H_9Br_2F$ $[M]^+$ 353.9050; found 353.9057.

General Procedure III for the Preparation of *syn* Diols 4 by Dihydroxylation of Stilbenes 2:[15] A mixture of *N*-methylmorpholine *N*-oxide [50% (w/w) aqueous solution; 937 mg, 8.0 mmol], acetone (8.0 mL), water (2.5 mL), and potassium osmate(VI) dihydrate (5 mg, 13.5 μmol, 0.26 mol-%) was stirred for 30 min at 25 °C. Then, stilbene **2** (5.0 mmol) was added, and the reaction mixture was stirred for the given time at 25 °C. After the reaction was complete, aqueous $FeSO_4$ (30 mL) was added, and the mixture was stirred for 30 min. The mixture was then extracted with ethyl acetate (4 × 10 mL), and the combined organic layers were washed with brine (2 × 10 mL), and dried with $MgSO_4$. The solvents were removed under reduced pressure, and the residue was filtered through silica gel (dichloromethane). Analytically pure *syn* diol **4** was obtained by crystallization of the crude product.

(1*RS*,2*RS*)-1,2-Bis(2-bromophenyl)ethane-1,2-diol (*rac*-*syn*-4a):[29] (*E*)-1,2-Bis(2-bromophenyl)ethene [(*E*)-**2a**] (1.69 g, 5 mmol) was used according to general procedure III, with a reaction time of 3 d. Crystallization from petroleum ether gave (1*RS*,2*RS*)-1,2-bis(2-bromophenyl)ethane-1,2-diol (*rac*-*syn*-**4a**) (1.67 g, 4.5 mmol, 90%) as a colorless solid. R_f = 0.12 (dichloromethane), m.p. 119–121 °C (ref.[29] m.p. 121–122 °C). IR: $\tilde{\nu}$ = 3283, 2935, 1591, 1568, 1490, 1440, 1429, 1384, 1336, 1296, 1276, 1224, 1196, 1115, 1046, 1020, 1005, 945, 844, 832, 752, 725, 690, 674, 630, 614, 570, 529, 488, 454 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.85 (s, 2 H), 5.32 (s, 2 H), 7.14 (ddd, ^3J = 7.9, ^3J = 7.4, ^4J = 1.8 Hz, 2 H), 7.34 (ddd, 2 × $^3J \approx$ 7.5, ^4J = 1.3 Hz, 2 H), 7.45 (dd, ^3J = 8.0, ^4J = 1.3 Hz, 2 H), 7.69 (dd, ^3J = 7.8, ^4J = 1.8 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 75.2, 122.9, 127.5, 129.6, 129.7, 132.8, 138.7 ppm. MS (EI): *m*/*z* (%) = 370 (1) $[M]^+$, 185 (100), 165 (34), 157 (79), 105 (60), 77 (75), 51 (92).

Asymmetric Dihydroxylation of (*E*)-1,2-bis(2-Bromophenyl)ethene [(*E*)-2a] Using the Sharpless Olefin Dihydroxylation Method[16]

(1*S*,2*S*)-1,2-Bis(2-bromophenyl)ethane-1,2-diol [(+)-4a]:[8b] Methanesulfonamide (740 mg), water (36 mL), and *tert*-butyl alcohol (36 mL) were placed into a round-bottomed flask equipped with a magnetic stirring bar. AD-mix α (10.55 g) was added, and the mixture was cooled to 0 °C. Then, (*E*)-1,2-bis(2-bromophenyl)ethene [(*E*)-**2a**] (2.45 g, 7.25 mmol) was added, and the mixture was stirred for 3 d at 0 °C. Na_2SO_3 was added, and the aqueous phase was separated. The aqueous phase was extracted with *tert*-butylmethyl ether (4 × 30 mL). The combined organic layers were washed with aqueous KOH (2 M; 2 × 50 mL), and brine (50 mL). The solvents were removed under reduced pressure. The residue was dissolved in dichloromethane, and the solution was filtered through silica gel. Most of the dichloromethane was then removed under reduced pressure, and crystallization from petroleum ether gave (1*S*,2*S*)-1,2-bis(2-bromophenyl)ethane-1,2-diol [(+)-**4a**] (2.32 g, 6.2 mmol, 86%) as a colorless solid, m.p. 106–107 °C. $[\alpha]_D$ = +33.0 (*c* = 1.0, ethanol) [ref.[8b] –33.0 (*c* = 1.28, ethanol) for the *R*,*R* enantiomer]. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.79–2.84 (m, 2 H), 5.30–5.35 (m, 2 H), 7.14 (ddd, ^3J = 7.9, ^3J = 7.7, ^4J = 1.8 Hz, 2 H), 7.34 (ddd, 2 × $^3J \approx$ 7.5, ^4J = 1.2 Hz, 2 H), 7.46 (dd, ^3J = 8.0, ^4J = 1.2 Hz, 2 H), 7.69 (dd, ^3J = 7.9, ^4J = 1.7 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 75.2, 122.9, 127.5, 129.5, 129.7, 132.8, 138.8 ppm. MS (EI): *m*/*z* (%) = 370 (1) $[M]^+$, 185 (100), 157 (5), 107 (9), 77 (52).

(1*RS*,2*SR*)-1,2-Bis(2-bromophenyl)ethane-1,2-diol (*meso*-4a):[30] (*Z*)-1,2-Bis(2-bromophenyl)ethene [(*Z*)-**2a**] (1.69 g, 5 mmol) was used according to general procedure III with a reaction time of 3 d. Crystallization from petroleum ether gave (1*RS*,2*SR*)-1,2-bis(2-bromophenyl)ethane-1,2-diol (*meso*-**4a**; 968 mg, 2.6 mmol; 52%) as a colorless solid, m.p. 113–114 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.65 (br. s, 2 H, OH), 5.56 (s, 2 H, 1-H and 2-H), 7.10 (ddd, ^3J = 7.9, ^3J = 7.2 Hz, ^4J = 2.1 Hz, 2 H), 7.21 (ddd, 2 × $^3J \approx$ 7.1, ^4J = 1.3 Hz, 2 H), 7.27 (dd, ^3J = 7.8, ^4J = 2.0 Hz, 2 H), 7.40 (dd, ^3J = 7.9, ^4J = 1.3 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 74.4, 124.0, 127.1, 129.2, 129.3, 132.1, 137.9 ppm. MS (EI): *m*/*z* (%) = 370 (1), 185 (100), 157 (5), 107 (8), 77 (41).

(1*RS*,2*RS*)-1,2-Bis(2-chlorophenyl)ethane-1,2-diol (*rac*-*syn*-4b):[31] (*E*)-1,2-bis(2-chlorophenyl)ethene [(*E*)-**2b**] (1.25 g, 5 mmol) was used according to general procedure III with a reaction time of 24 h. Crystallization from petroleum ether gave (1*RS*,2*RS*)-1,2-bis(2-chlorophenyl)ethane-1,2-diol (*rac*-*syn*-**4b**; 1.13 g, 4.0 mmol, 80%) as a colorless solid. R_f = 0.12 (dichloromethane), m.p. 146–147 °C (ref.[31] m.p. 145–146 °C). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.78–2.84 (m, 2 H), 5.32–5.38 (m, 2 H), 7.18–7.34 (m, 6 H), 7.66 (dd, ^3J = 7.7, ^4J = 1.6 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 73.0, 126.8, 129.09, 129.13, 129.4, 132.6, 137.2 ppm. MS (EI): *m*/*z* (%) = 282 (1), 165 (1), 141 (100), 107 (6), 77 (25).

(1*RS*,2*RS*)-1-(2-Bromophenyl)-2-(2-chlorophenyl)ethane-1,2-diol (*rac*-*syn*-4c): (*E*)-1-(2-Bromostyryl)-2-chlorobenzene [(*E*)-**2c**] (1.47 g, 5 mmol) was used according to general procedure III with a reaction time of 24h. Crystallization from petroleum ether gave (1*RS*,2*RS*)-1-(2-bromophenyl)-2-(2-chlorophenyl)ethane-1,2-diol (*rac*-*syn*-**4c**; 1.52 g, 4.65 mmol, 93%) as a colorless solid. R_f = 0.10 (dichloromethane), m.p. 141–142 °C. IR: $\tilde{\nu}$ = 3277, 1593, 1568, 1471, 1436, 1385, 1337, 1276, 1193, 1118, 1024, 1006, 844, 752, 728, 709, 679, 630, 614, 570, 532, 464, 455 cm^{-1}. UV (CH_3CN): λ_{max} (log ε) = 263 (2.35) nm. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 2.79 (s, 2 H, OH), 5.31–5.38 (m, 2 H, 1-H and 2-H) 7.14 (ddd, $^3J_{4'\text{-H},3'\text{-H}}$ = 7.8, $^3J_{4'\text{-H},5'\text{-H}}$ = 7.6 Hz, $^4J_{4'\text{-H},6'\text{-H}}$ = 1.1 Hz, 1 H, 4′-H), 7.22 (ddd, 2 × $^3J \approx$ 7.6, $^4J_{4''\text{-H},6''\text{-H}}$ = 1.1 Hz, 1 H, 4′′-H), 7.27 (dd, $^3J_{3''\text{-H},4''\text{-H}}$ = 7.9, $^4J_{3''\text{-H},5''\text{-H}}$ = 1.3 Hz, 1 H, 3′′-H), 7.30 (ddd, ^3J = 7.4, ^3J = 7.3 Hz, $^4J_{5''\text{-H},3''\text{-H}}$ = 1.3 Hz, 1 H, 5′′-H), 7.34 (ddd, ^3J = 7.6, ^3J = 7.5 Hz, $^4J_{5'\text{-H},3'\text{-H}}$ = 0.9 Hz, 1 H, 5′-H), 7.46 (dd, $^3J_{3'\text{-H},4'\text{-H}}$ = 8.0, $^4J_{3'\text{-H},5'\text{-H}}$ = 1.0 Hz, 1 H, 3′-H), 7.66–7.70 (m, 2 H, 6′-H and 6′′-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 73.1 (C-1 or C-2), 75.1 (C-1 or C-2), 122.9 (C-2′), 127.0 (C-5′′), 127.6 (C-5′), 129.3 (C-4′′), 129.4 (C-4′, C-6′, C-3′′ or C-6′′), 129.61 (C-4′, C-6′, C-3′′ or C-6′′), 129.64 (C-4′, C-6′, C-3′′ or C-6′′), 129.66 (C-4′, C-6′, C-3′′ or C-6′′), 132.88 (C-2′′), 132.9 (C-3′), 137.3 (C-1′′), 139.0 (C-1′) ppm. MS (EI): *m*/*z* (%) = 326 (6) $[M]^+$, 309 (2), 247 (3), 229 (3), 185 (79), 157 (8), 141 (100), 105 (11), 77 (64). HRMS (EI): calcd. for $C_{14}H_{12}BrClO_2$ $[M]^+$: 325.9709; found 325.9708.

(1*RS*,2*RS*)-1-(2-Bromo-5-methoxyphenyl)-2-(2-bromophenyl)ethane-1,2-diol (*rac*-*syn*-4d): (*E*)-2-(2-Bromostyryl)-1-bromo-4-methoxybenzene [(*E*)-**3d**] (1.84 g, 5 mmol) was used according to general procedure III with a reaction time of 3 d. Crystallization from petroleum ether gave (1*RS*,2*RS*)-1-(2-bromo-5-methoxyphenyl)-2-(2-bromophenyl)ethane-1,2-diol (*rac*-*syn*-**4d**; 1.49 g, 3.7 mmol, 74%) as a colorless solid. R_f = 0.08 (dichloromethane), m.p. 99–100 °C.

IR: $\tilde{\nu}$ = 3392, 1599, 1571, 1472, 1412, 1252, 1192, 1160, 1135, 1119, 1046, 1013, 926, 895, 874, 840, 806, 755, 726, 680, 641, 618, 596, 549, 470, 452 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 281 (3.64), 207 (4.52) nm. ^1H NMR (500 MHz, $CDCl_3$): δ = 2.63 (s, 2 H, OH), 3.81 (s, 3 H, OCH_3), 5.27 (d, $^3J_{1\text{-}H,2\text{-}H}$ = 5.6 Hz, 1 H, 1-H), 5.31 (d, $^3J_{2\text{-}H,1\text{-}H}$ = 5.7 Hz, 1 H, 2-H), 6.71 (dd, $^3J_{4'\text{-}H,3'\text{-}H}$ = 8.8, $^4J_{4'\text{-}H,6'\text{-}H}$ = 3.1 Hz, 1 H, 4′-H), 7.14 (ddd, $^3J_{4''\text{-}H,3''\text{-}H} \approx 7.7$, $^3J_{4''\text{-}H,5''\text{-}H} \approx 7.7$ Hz, $^4J_{4''\text{-}H,6''\text{-}H}$ = 1.2 Hz, 1 H, 4″-H), 7.24 (d, $^4J_{6'\text{-}H,4'\text{-}H}$ = 3.1 Hz, 1 H, 6′-H), 7.32 (d, $^3J_{3'\text{-}H,4'\text{-}H}$ = 8.8 Hz, 1 H, 3′-H), 7.34 (ddd, $^3J_{5''\text{-}H,4''\text{-}H} \approx 7.5$, $^3J_{5''\text{-}H,6''\text{-}H} \approx 7.5$ Hz, $^4J_{5''\text{-}H,3''\text{-}H}$ = 1.2 Hz, 1 H, 5″-H), 7.46 (dd, $^3J_{3''\text{-}H,4''\text{-}H}$ = 7.8, $^3J_{3''\text{-}H,5''\text{-}H}$ = 1.7 Hz, 1 H, 3″-H), 7.69 (dd, $^3J_{6''\text{-}H,5''\text{-}H}$ = 7.8, $^4J_{6''\text{-}H,5''\text{-}H}$ = 1.7 Hz, 1 H, 6″-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 55.6 (OCH_3), 75.18 (C-1 or C-2), 75.20 (C-1 or C-2), 113.2 (C-2′), 114.8 (C-6′), 115.9 (C-4′), 123.0 (C-2″), 127.5 (C-5″), 129.6 (C-4″), 129.7 (C-6″), 132.8 (C-3″), 133.4 (C-3′), 138.7 (C-1″), 139.6 (C-1′), 159.0 (C-5′) ppm. MS (EI): *m/z* (%) = 400 (<1) $[M]^+$, 216 (100), 185 (22), 137 (10), 108 (54), 77 (24), 51 (5). HRMS (EI): calcd. for $C_{15}H_{14}Br_2O_3$ $[M]^+$ 399.9304; found 399.9307.

(1*RS*,2*RS*)-1,2-Bis(2-bromo-5-methoxyphenyl)ethane-1,2-diol (*rac-syn*-4e): (*E*)-1,2-Bis(2-bromo-5-methoxyphenyl)ethene [(*E*)-**2e**] (1.99 g, 5 mmol) was used according to general procedure III with a reaction time of 3 d. Crystallization from petroleum ether gave (1*RS*,2*RS*)-1,2-bis(2-bromo-5-methoxyphenyl)ethane-1,2-diol (*rac-syn*-**4e**; 1.21 g, 2.8 mmol, 56%) as a colorless solid. R_f = 0.09 (dichloromethane), m.p. 151 °C. IR: $\tilde{\nu}$ = 3497, 2932, 1654, 1601, 1571, 1470, 1422, 1300, 1260, 1213, 1161, 1127, 1089, 1051, 1032, 1011, 927, 898, 870, 833, 800, 767, 755, 728, 646, 627, 595, 538, 509, 479, 463, 436 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 284 (3.39), 203 (4.66) nm. ^1H NMR (300 MHz, $CDCl_3$): δ = 2.49 (s, 2 H, OH), 3.82 (s, 6 H, OCH_3), 5.28 (s, 2 H, 1-H and 2-H), 6.71 (dd, $^3J_{4'\text{-}H,3'\text{-}H} = {}^3J_{4''\text{-}H,3''\text{-}H}$ = 8.8, $^4J_{4'\text{-}H,6'\text{-}H} = {}^4J_{4''\text{-}H,6''\text{-}H}$ = 3.1 Hz, 2 H, 4′-H and 4″-H), 7.24 (d, $^4J_{6'\text{-}H,4'\text{-}H} = {}^4J_{6''\text{-}H,4''\text{-}H}$ = 3.3 Hz, 2 H, 6′-H and 6″-H), 7.33 (d, $^3J_{3'\text{-}H,4'\text{-}H} = {}^3J_{3''\text{-}H,4''\text{-}H}$ = 8.8 Hz, 2 H, 3′-H and 3″-H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 55.6 (OCH_3), 75.2 (C-1 and C-2), 113.4 (C-2′ and C-2″), 114.8 (C-6′ and C-6″), 116.0 (C-4′ and C-4″), 133.4 (C-3′ and C-3″), 139.6 (C-1′ and C-1″), 159.0 (C-5′ and C-5″) ppm. MS (EI): *m/z* (%) = 430 (1) $[M]^+$, 216 (96), 187 (12), 172 (7), 137 (19), 108 (100), 78 (17), 63 (13). HRMS (ESI): calcd. for $C_{16}H_{16}Br_2O_4Na$ $[M + Na]^+$ 452.9308; found 452.9325.

3-Bromo-4-[(1*RS*,2*RS*)-2-(2-bromophenyl)-1,2-dihydroxyethyl]-benzonitrile (*rac-syn*-4f): (*E*)-4-(2-Bromostyryl)-3-bromobenzonitrile [(*E*)-**2f**] (1.81 g, 5 mmol) was used according to general procedure III with a reaction time of 3 d. Crystallization from petroleum ether gave 3-bromo-4-[(1*RS*,2*RS*)-2-(2-bromophenyl)-1,2-dihydroxyethyl]benzonitrile (*rac-syn*-**4f**; 1.87 g, 4.7 mmol, 94%) as a colorless solid. R_f = 0.10 (dichloromethane), m.p. 110–111 °C. IR: $\tilde{\nu}$ = 3529, 3446, 3075, 2233, 1547, 1479, 1464, 1435, 1385, 1334, 1306, 1266, 1188, 1118, 1081, 1037, 1022, 904, 839, 821, 785, 773, 745, 701, 664, 615, 539, 509, 471, 443 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 289 (3.00), 281 (3.07), 241 (4.11) nm. ^1H NMR (500 MHz, $CDCl_3$): δ = 2.80 (s, 1 H, OH), 3.05 (s, 1 H, OH), 5.25 (d, $^3J_{2\text{-}H,1\text{-}H}$ = 5.8 Hz, 1 H, 2-H), 5.30 (d, $^3J_{1\text{-}H,2\text{-}H}$ = 5.8 Hz, 1 H, 1-H), 7.17 (ddd, $^3J_{4''\text{-}H,3''\text{-}H} \approx 7.7$, $^3J_{4''\text{-}H,5''\text{-}H} \approx 7.7$ Hz, $^4J_{4''\text{-}H,6''\text{-}H}$ = 1.7 Hz, 1 H, 4″-H), 7.36 (ddd, $^3J_{5''\text{-}H,4''\text{-}H} \approx 7.6$, $^3J_{5''\text{-}H,6''\text{-}H} \approx 7.6$ Hz, $^4J_{5''\text{-}H,3''\text{-}H}$ = 1.2 Hz, 1 H, 5″-H), 7.46 (dd, $^3J_{3''\text{-}H,4''\text{-}H}$ = 8.0, $^4J_{3''\text{-}H,5''\text{-}H}$ = 1.2 Hz, 1 H, 3″-H), 7.62 (dd, $^3J_{5'\text{-}H,6'\text{-}H}$ = 7.9, $^4J_{5'\text{-}H,3'\text{-}H}$ = 1.7 Hz, 1 H, 5′-H), 7.69 (dd, $^3J_{6''\text{-}H,5''\text{-}H}$ = 7.9, $^4J_{6''\text{-}H,4''\text{-}H}$ = 1.7 Hz, 1 H, 6″-H), 7.72 (d, $^4J_{3'\text{-}H,5'\text{-}H}$ = 1.6 Hz, 1 H, 3′-H), 7.86 (d, $^3J_{6'\text{-}H,5'\text{-}H}$ = 8.1 Hz, 1 H, 6′-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 74.9 (C-1), 75.0 (C-2), 113.2 (C-4′), 117.2 (CN), 122.7 (C-2″), 123.0 (C-2′), 127.7 (C-5″), 129.7 (C-6″), 130.0 (C-4″), 130.70 (C5′ or C-6′), 130.73 (C5′ or C-6′), 132.9 (C-3″), 135.8 (C-3′), 138.1 (C-1″), 144.4 (C-1′) ppm. MS (EI): *m/z* (%) = 395 (<1) $[M]^+$, 211 (100), 185 (50), 157 (8), 131 (4), 102 (7), 77 (41), 51 (8). HRMS (EI): calcd. for $C_{15}H_{11}Br_2NO_2$ $[M]^+$ 394.9151; found 394.9152.

(1*RS*,2*RS*)-1-(2-Bromo-5-chlorophenyl)-2-(2-bromophenyl)ethane-1,2-diol (*rac-syn*-4g): (*E*)-2-(2-Bromostyryl)-1-bromo-4-chlorobenzene [(*E*)-**2g**] (1.86 g, 5 mmol) was used according to general procedure III with a reaction time of 3 d. Crystallization from petroleum ether gave (1*RS*,2*RS*)-1-(2-bromo-5-chlorophenyl)-2-(2-bromophenyl)ethane-1,2-diol (*rac-syn*-**4g**; 1.87 g, 4.6 mmol, 92%) as a colorless solid. R_f = 0.12 (dichloromethane), m.p. 124–125 °C. IR: $\tilde{\nu}$ = 3321, 2943, 1759, 1589, 1458, 1431, 1385, 1322, 1297, 1267, 1188, 1118, 1097, 1062, 1022, 1003, 945, 900, 882, 846, 833, 815, 755, 726, 678, 637, 617, 593, 543, 479, 465 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 212 (2.67) nm. ^1H NMR (500 MHz, $CDCl_3$): δ = 2.79 (s, 1 H, OH), 2.91 (s, 1 H, OH), 5.25 (d, $^3J_{1\text{-}H,2\text{-}H}$ or $^3J_{2\text{-}H,1\text{-}H}$ = 6.3 Hz, 1 H, 1-H or 2-H), 5.27 (d, $^3J_{1\text{-}H,2\text{-}H}$ or $^3J_{2\text{-}H,1\text{-}H}$ = 6.3 Hz, 1 H, 1-H or 2-H), 7.12 (dd, $^3J_{4'\text{-}H,3'\text{-}H}$ = 8.5, $^4J_{4'\text{-}H,6'\text{-}H}$ = 2.7 Hz, 1 H, 4′-H), 7.15 (ddd, $^3J_{4''\text{-}H,3''\text{-}H} \approx 7.6$, $^3J_{4''\text{-}H,5''\text{-}H} \approx 7.6$ Hz, $^4J_{4''\text{-}H,6''\text{-}H}$ = 1.7 Hz, 1 H, 4″-H), 7.35 (ddd, $^3J_{5''\text{-}H,4''\text{-}H} \approx 7.7$, $^3J_{5''\text{-}H,6''\text{-}H} \approx 7.7$ Hz, $^4J_{5''\text{-}H,3''\text{-}H}$ = 1.2 Hz, 1 H, 5″-H), 7.36 (d, $^3J_{3'\text{-}H,4'\text{-}H}$ = 8.5 Hz, 1 H, 3′-H), 7.46 (dd, $^3J_{3''\text{-}H,4''\text{-}H}$ = 8.0 Hz, 1 H, 3″-H), 7.69 (dd, $^3J_{6''\text{-}H,5''\text{-}H}$ = 7.8, $^4J_{6''\text{-}H,4''\text{-}H}$ = 1.7 Hz, 1 H, 6″-H), 7.72 (d, $^4J_{6'\text{-}H,4'\text{-}H}$ = 2.6 Hz, 1 H, 6′-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 74.9 (C-1 or C-2), 75.1 (C-1 or C-2), 120.5 (C-2′), 122.8 (C-2″), 127.6 (C-5″), 129.6 (C-4′), 129.69 (C-6″), 129.73 (C-4″), 130.0 (C-6′), 132.9 (C-3″), 133.67 (C-5′), 133.69 (C-3′), 138.4 (C-1″), 140.6 (C-1′) ppm. MS (EI): *m/z* (%) = 404 (<1) $[M]^+$, 222 (21), 187 (100), 157 (10), 112 (14), 77 (44), 51 (8). HRMS (EI): calcd. for $C_{14}H_{11}Br_2ClO_2$ $[M]^+$ 403.8809; found 403.8793.

(1*RS*,2*RS*)-1,2-Bis(2-bromo-5-chlorophenyl)ethane-1,2-diol (*rac-syn*-4h): (*E*)-1,2-Bis(2-bromo-5-chlorophenyl)ethene [(*E*)-**2h**] (2.04 g, 5 mmol) was used according to general procedure III with a reaction time of 3 d. Crystallization from petroleum ether gave (1*RS*,2*RS*)-1,2-bis(2-bromo-5-chlorophenyl)ethane-1,2-diol (*rac-syn*-**4h**; (2.07 g, 4.7 mmol, 93%) as a colorless solid. R_f = 0.13 (dichloromethane), m.p. 144–146 °C. IR: $\tilde{\nu}$ = 3331, 1738, 1458, 1387, 1305, 1188, 1126, 1100, 1054, 1022, 935, 893, 805, 783, 716, 641, 566, 541, 510, 488, 461, 429, 395 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 274 (2.67) nm. ^1H NMR (300 MHz, $CDCl_3$): δ = 2.85 (s, 2 H, OH), 5.21 (s, 2 H, 1-H and 2-H), 7.13 (dd, $^3J_{4'\text{-}H,3'\text{-}H} = {}^3J_{4''\text{-}H,3''\text{-}H}$ = 8.5, $^4J_{4'\text{-}H,6'\text{-}H} = {}^4J_{4''\text{-}H,6''\text{-}H}$ = 2.6 Hz, 2 H, 4′-H and 4″-H), 7.36 (d, $^3J_{3'\text{-}H,4'\text{-}H} = {}^3J_{3''\text{-}H,4''\text{-}H}$ = 8.6 Hz, 2 H, 3′-H and 3″-H), 7.72 (d, $^4J_{6'\text{-}H,4'\text{-}H} = {}^4J_{6''\text{-}H,4''\text{-}H}$ = 2.6 Hz, 2 H, 6′-H and 6″-H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 74.9 (C-1 and C-2), 120.4 (C-2′ and C-2″), 140.2 (C-1′ and C-1″), 129.8 (C-4′ and C-4″), 130.0 (C-6′ and C-6″), 133.8 (overlapped, C-5′ and C-5″), 133.8 (overlapped, C-3′ and C-3″) ppm. MS (ESI): *m/z* (%) = 439 (100) $[M + H]^+$, 381 (24), 357 (6), 339 (13), 325 (11), 309 (21), 293 (9), 265 (11), 253 (7), 220 (33), 171 (5). HRMS (EI): calcd. for $C_{14}H_{10}Br_2Cl_2O_2$ $[M]^+$ 437.8419; found 437.8397.

(1*RS*,2*RS*)-1-(2-Bromo-5-fluorophenyl)-2-(2-bromophenyl)ethane-1,2-diol (*rac-syn*-4i): (*E*)-2-(2-Bromostyryl)-1-bromo-4-fluorobenzene [(*E*)-**2i**] (1.78 g, 5 mmol) was used according to general procedure III with a reaction time of 3 d. Crystallization from petroleum ether gave (1*RS*,2*RS*)-1-(2-bromo-5-fluorophenyl)-2-(2-bromophenyl)ethane-1,2-diol (*rac-syn*-**4i**) (1.64 g, 4.2 mmol, 84%) as a colorless solid. R_f = 0.11 (dichloromethane), m.p. 114–115 °C. IR: $\tilde{\nu}$ = 3297, 1737, 1580, 1467, 1434, 1406, 1265, 1231, 1193, 1155, 1107, 1047, 1024, 1006, 945, 870, 844, 833, 813, 773, 754, 724, 680, 640, 617, 594, 533, 471, 458, 402 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$)

= 270 (3.07), 214 (4.35) nm. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 2.78 (s, 1 H, OH), 2.90 (s, 1 H, OH), 5.26 (d, $^3J_{1\text{-H},2\text{-H}}$ or $^3J_{2\text{-H},1\text{-H}}$ = 5.8 Hz, 1 H, 1-H or 2-H), 5.27 (d, $^3J_{1\text{-H},2\text{-H}}$ or $^3J_{2\text{-H},1\text{-H}}$ = 5.8 Hz, 1 H, 1-H or 2-H), 6.88 (ddd, $^3J_{4'\text{-H},5'\text{-F}}$ = 8.8, $^3J_{4'\text{-H},3'\text{-H}}$ = 7.6 Hz, $^4J_{4'\text{-H},6'\text{-H}}$ = 3.2 Hz, 1 H, 4′-H), 7.16 (ddd, $^3J_{4''\text{-H},3''\text{-H}}$ = 8.0, $^3J_{4''\text{-H},5''\text{-H}}$ = 7.4 Hz, $^4J_{4''\text{-H},6''\text{-H}}$ = 1.7 Hz, 1 H, 4′′-H), 7.35 (ddd, $^3J_{5''\text{-H},4''\text{-H}} \approx 7.5$, $^3J_{5''\text{-H},6''\text{-H}} \approx 7.5$ Hz, $^4J_{5''\text{-H},3''\text{-H}}$ = 1.3 Hz, 1 H, 5′′-H), 7.40 (dd, $^3J_{3'\text{-H},4'\text{-H}}$ = 8.8, $^4J_{3'\text{-H},5'\text{-F}}$ = 5.3 Hz, 1 H, 3′-H), 7.45–7.48 (m, overlapped, 2 H, 6′-H and 3′′-H), 7.69 (dd, $^3J_{6''\text{-H},5''\text{-H}}$ = 7.8, $^4J_{6''\text{-H},4''\text{-H}}$ = 1.8 Hz, 1 H, 6′′-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 74.9 (d, $J_{C,F}$ = 1.1 Hz, C-1), 75.1 (C-2), 116.7 (d, $J_{C,F}$ = 2.0 Hz, C-2′), 116.8 (d, $J_{C,F}$ = 22.9 Hz, C-4′), 117.0 (d, $J_{C,F}$ = 23.8 Hz, C-6′), 122.8 (C-2′′), 127.6 (C-5′′), 129.70 (C-4′′ or C-6′′), 129.72 (C-4′′ or C-6′′), 132.9 (C-3′′), 133.9 (d, $J_{C,F}$ = 7.9 Hz, C-3′), 138.5 (C-1′′), 141.1 (d, $J_{C,F}$ = 7.1 Hz, C-1′), 162.0 (d, $J_{C,F}$ = 246.7 Hz, C-5′) ppm. MS (ESI): *m*/*z* (%) = 389 (29) [M + H]$^+$, 309 (100), 287 (76), 281 (20), 255 (13), 203 (17). HRMS (EI): calcd. for $C_{14}H_{11}Br_2FO_2$ [M]$^+$ 387.9104; found 387.9108.

General Procedure IV for the Intramolecular Bis-*O*-arylation of 1,2-Bis(2-haloaryl)ethane-1,2-diols 4: A 10 mL vial was equipped with a magnetic stirring bar, and loaded with K_3PO_4 (1.70 g, 8 mmol), Cu^{II} oxinate (70 mg, 0.2 mmol), KI (332 mg, 2.0 mmol), and 1,2-bis(2-haloaryl)ethane-1,2-diol **4** (2.0 mmol) under air. The vial was sealed, evacuated, and refilled with argon three (3×), then water (2 mL) and acetonitrile (2 mL) were added. The reaction mixture was stirred at 120 °C for 3 d. Brine (50 mL) was then added, and the mixture was extracted with ethyl acetate (3 × 50 mL). The combined organic layers were dried with Na_2SO_4, and concentrated under reduced pressure. The residue was dissolved in dichloromethane, and the solution was filtered through silica gel and concentrated under reduced pressure. Analytically pure product was obtained by column chromatography or crystallization.

(4b*RS*,9b*RS*)-4b,9b-Dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-5a):[11i] (1*RS*,2*RS*)-1,2-Bis(2-bromophenyl)ethane-1,2-diol (*rac-syn*-**4a**; 746 mg, 2.0 mmol), Cu^{II} oxinate (69 mg, 0.2 mmol), KI (334 mg, 2.0 mmol), and K_3PO_4 (1.70 g, 8.0 mmol) were used according to general procedure IV. After work up, (4b*RS*,9b*RS*)-4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-**5a**; 379 mg, 1.8 mmol, 90%) was isolated. Crystallization from methanol gave analytically pure (4b*RS*,9b*RS*)-4b,9b-dihydrobenzofuro[3,2-*b*]-benzofuran (*rac-cis*-**5a**) as colorless needles. R_f = 0.32 (petroleum ether/dichloromethane, 7:3), m.p. 117–120 °C (ref.[11i] m.p. 118–119 °C). IR: $\tilde{\nu}$ = 2964, 1598, 1478, 1461, 1312, 1221, 1166, 1100, 1015, 915, 933, 842, 805, 744, 610, 561, 504, 440, 411 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.29 (s, 2 H, 4b-H and 9b-H), 6.87 (d, $^3J_{1\text{-H},2\text{-H}} = {}^3J_{6\text{-H},7\text{-H}}$ = 8.1 Hz, 2 H, 1-H and 6-H), 6.97 (ddd, $^3J_{3\text{-H},2\text{-H}} = {}^3J_{8\text{-H},7\text{-H}} \approx 7.4$, $^3J_{3\text{-H},4\text{-H}} = {}^3J_{8\text{-H},9\text{-H}} \approx 7.4$ Hz, $^4J_{3\text{-H},1\text{-H}} = {}^3J_{8\text{-H},6\text{-H}}$ = 0.9 Hz, 2 H, 3-H and 8-H), 7.28 (ddd, $^3J_{2\text{-H},1\text{-H}} = {}^3J_{7\text{-H},6\text{-H}}$ = 8.2, $^3J_{2\text{-H},3\text{-H}} = {}^3J_{7\text{-H},8\text{-H}}$ = 7.4 Hz, $^4J_{2\text{-H},4\text{-H}} = {}^4J_{7\text{-H},9\text{-H}}$ = 1.2 Hz, 2 H, 2-H and 7-H), 7.54 (dd, $^3J_{4\text{-H},3\text{-H}} = {}^3J_{9\text{-H},8\text{-H}}$ = 7.6, $^4J_{4\text{-H},2\text{-H}} = {}^4J_{9\text{-H},7\text{-H}}$ = 1.3 Hz, 2 H, 4-H and 9-H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 86.5 (C-4b and C-9b) 110.8 (C-1 and C-6), 121.1 (C-3 and C-8), 124.4 (C-4a and C-9a), 126.5 (C-9 and C-4), 131.3 (C-2 and C-7), 160.0 (C-10a and C-5a) ppm. MS (EI): *m*/*z* (%) = 210 (100) [M]$^+$, 181 (39), 152 (18), 105 (11), 76 (11).

(4b*S*,9b*S*)-4b,9b-Dihydrobenzofuro[3,2-*b*]benzofuran [(–)-5a]:[8a] (1*S*,2*S*)-1,2-Bis(2-bromophenyl)ethane-1,2-diol [(+)-**4a**] (746 mg, 2.0 mmol), Cu^{II} oxinate (69 mg, 0.2 mmol), KI (1310 mg, 8.0 mmol), and K_3PO_4 (1.70 g, 8.0 mmol) were used according to general procedure IV. After work up, (4b*S*,9b*S*)-4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran [(–)-**5a**] (355 mg, 1.7 mmol, 85%) was isolated. $[\alpha]_D$ = –413.7 (*c* = 0.53, chloroform) [ref.[8a] +371 (*c* = 0.5, chloroform) for the *R*,*R* enantiomer]. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.29 (s, 2 H), 6.87 (d, ^3J = 8.0 Hz, 2 H), 6.98 (dd, ^3J = 7.5, ^3J = 7.4 Hz, 2 H), 7.28 (ddd, $2 \times {}^3J \approx 7.7$, ^4J = 1.4 Hz, 2 H), 7.54 (d, ^3J = 7.5 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 86.4, 110.8, 121.1, 124.4, 126.5, 131.3, 160.0 ppm. MS (EI): *m*/*z* (%) = 210 (100) [M]$^+$, 181 (25), 152 (8), 105 (6), 76 (5).

(4b*RS*,9b*RS*)-3-Methoxy-4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-5b): (1*RS*,2*RS*)-1-(2-Bromo-5-methoxyphenyl)-2-(2-bromophenyl)ethane-1,2-diol (*rac-syn*-**4d**; 806 mg, 2.0 mmol), Cu^{II} oxinate (70 mg, 0.2 mmol), KI (331 mg, 2.0 mmol), and K_3PO_4 (1.70 g, 8.0 mmol) were used according to general procedure IV. Flash chromatography over silica gel (petroleum ether/dichloromethane, 1:1) gave (4b*RS*,9b*RS*)-3-methoxy-4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-**5b**; (308 mg, 1.28 mmol, 64%) as a colorless solid. R_f = 0.29 (petroleum ether/dichloromethane, 1:1), m.p. 167–168 °C. IR: $\tilde{\nu}$ = 2833, 1596, 1484, 1464, 1430, 1279, 1141, 1105, 1030, 979, 951, 876, 846, 807, 778, 746, 716, 635, 591, 549, 515, 445, 419 cm^{-1}. UV (CH_3CN): λ_{max} (logε) = 306 (3.53), 290 (3.61), 207 (4.27) nm. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 3.79 (s, 3 H, OCH_3), 6.26 (d, $^3J_{4b\text{-H},9b\text{-H}}$ = 7.5 Hz, 1 H, 4b-H), 6.28 (d, $^3J_{9b\text{-H},4b\text{-H}}$ = 7.4 Hz, 1 H, 9b-H), 6.78 (d, $^3J_{1\text{-H},2\text{-H}}$ = 8.8 Hz, 1 H, 1-H), 6.85 (dd overlapped, $^3J_{2\text{-H},1\text{-H}}$ = 8.9, $^4J_{2\text{-H},4\text{-H}}$ = 2.8 Hz, 1 H, 2-H), 6.87 (d, overlapped, $^3J_{6\text{-H},7\text{-H}}$ = 8.1 Hz, 1 H, 6-H), 6.97 (dd, $^3J_{8\text{-H},7\text{-H}} \approx 7.5$, $^3J_{8\text{-H},9\text{-H}} \approx 7.5$ Hz, 1 H, 8-H), 7.08 (d, $^4J_{4\text{-H},2\text{-H}}$ = 2.8 Hz, 1 H, 4-H), 7.28 (ddd, $^3J_{7\text{-H},6\text{-H}} \approx 7.7$, $^3J_{7\text{-H},8\text{-H}} \approx 7.7$ Hz, $^4J_{7\text{-H},9\text{-H}}$ = 1.4 Hz, 1 H, 7-H), 7.53 (ddd, $^3J_{9\text{-H},8\text{-H}}$ = 7.6, $^4J_{9\text{-H},7\text{-H}}$ = 1.4 Hz, *J* = 0.7 Hz, 1 H, 9-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 56.1 (OCH_3), 86.7 (C-9b), 86.9 (C-4b), 110.8 (C-6), 110.9 (C-4), 111.1 (C-1), 118.0 (C-2), 121.2 (C-8), 124.6 (C-9a), 124.8 (C-4a), 126.5 (C-9), 131.3 (C-7), 154.0 (C-10a), 154.5 (C-3), 159.9 (C-5a) ppm. MS (EI, 70 eV): *m*/*z* (%) = 240 (100) [M]$^+$, 225 (56), 211 (27), 197 (49), 181 (10), 169 (20), 152 (5), 141 (19), 120 (11), 115 (16). HRMS (EI): calcd. for $C_{15}H_{12}O_3$ [M]$^+$ 240.0781; found 240.0759.

(4b*RS*,9b*RS*)-3,8-Dimethoxy-4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-5c): (1*RS*,2*RS*)-1,2-Bis(2-bromo-5-methoxyphenyl)ethane-1,2-diol (*rac-syn*-**4e**; 865 mg, 2.0 mmol), Cu^{II} oxinate (70 mg, 0.2 mmol), KI (331 mg, 2.0 mmol), and K_3PO_4 (1.70 g, 8.0 mmol) were used according to general procedure IV. Flash chromatography over silica gel (dichloromethane) gave (4b*RS*,9b*RS*)-3,8-dimethoxy-4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-**5c**; 443 mg, 1.64 mmol, 82%) as a pale yellow solid. R_f = 0.24 (dichloromethane), m.p. 181–183 °C. IR: $\tilde{\nu}$ = 2836, 1611, 1485, 1468, 1449, 1430, 1308, 1287, 1235, 1145, 1142, 1025, 954, 857, 799, 747, 599, 510, 465, 448 cm^{-1}. UV (CH_3CN): λ_{max} (logε) = 304 (3.88), 226 (4.06), 205 (4.65) nm. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.79 (s, 6 H, OCH_3) 6.25 (s, 2 H, 4b-H and 9b-H), 6.77 (d, $^3J_{1\text{-H},2\text{-H}} = {}^3J_{6\text{-H},7\text{-H}}$ = 8.8 Hz, 2 H, 1-H and 6-H), 6.85 (dd, $^3J_{2\text{-H},1\text{-H}} = {}^3J_{7\text{-H},6\text{-H}}$ = 8.8, $^4J_{2\text{-H},4\text{-H}} = {}^4J_{7\text{-H},9\text{-H}}$ = 2.8 Hz, 2 H, 2-H and 7-H), 7.06 (d, $^4J_{4\text{-H},2\text{-H}} = {}^4J_{9\text{-H},7\text{-H}}$ = 2.5 Hz, 2 H, 4-H and 9-H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 56.0 (OCH_3), 87.1 (C-4b and C-9b), 110.8 (C-4 and C-9), 111.1 (C-1 and C-6), 117.9 (C-2 and C-7) 125.0 (C-4a and C-9a), 153.9 (C-10a and C-5a), 154.5 (C-3 and C-8) ppm. MS (EI, 70 eV): *m*/*z* (%) = 270 (100) [M]$^+$, 255 (57), 241 (9), 227 (27), 211 (7), 184 (8), 135 (7) ppm. HRMS (EI): calcd. for $C_{16}H_{14}O_4$ [M]$^+$ 270.0887; found 270.0887.

(4b*RS*,9b*RS*)-4b,9b-Dihydrobenzofuro[3,2-*b*]benzofuran-2-carbonitrile (*rac-cis*-5d): 3-Bromo-4-[(1*RS*,2*RS*)-2-(2-bromophenyl)-1,2-dihydroxyethyl]benzonitrile (*rac-syn*-**4f**; 798 mg, 2.0 mmol), Cu^{II} oxinate (70 mg, 0.2 mmol), KI (331 mg, 2.0 mmol), and K_3PO_4 (1.70 g, 8.0 mmol) were used according to general procedure IV. Flash chromatography over silica gel (petroleum ether/dichloro-

methane, 1:1) gave (4b*RS*,9b*RS*)-4b,9b-dihydrobenzofuro[3,2-*b*]-benzofuran-2-carbonitrile (*rac-cis*-**5d**; 369 mg, 1.1 mmol, 55%) as a pale yellow oil. R_f = 0.31 (dichloromethane). IR: $\tilde{\nu}$ = 2927, 2219, 1721, 1607, 1464, 1429, 1274, 1236, 1172, 1121, 1073, 1016, 960, 884, 846, 810, 746, 707, 689, 632, 549, 500, 462 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 316 (3.63), 272 (3.99), 218 (4.09) nm. ^1H NMR (500 MHz, $CDCl_3$): δ = 6.28 (d, $^3J_{4b\text{-}H,9b\text{-}H}$ = 7.5 Hz, 1 H, 4b-H), 6.39 (d, $^3J_{9b\text{-}H,4b\text{-}H}$ = 7.4 Hz, 1 H, 9b-H), 6.88 (d, $^3J_{6\text{-}H,7\text{-}H}$ = 8.0 Hz, 1 H, 6-H), 7.01 (dd, $^3J_{8\text{-}H,7\text{-}H} \approx 7.7$, $^3J_{8\text{-}H,9\text{-}H} \approx 7.7$ Hz, 1 H, 8-H), 7.11 (s, 1 H, 1-H), 7.30 (d, $^3J_{3\text{-}H,4\text{-}H}$ = 7.5 Hz, 1 H, 3-H), 7.31 (dd, $^3J_{7\text{-}H,6\text{-}H} \approx 7.7$, $^3J_{7\text{-}H,8\text{-}H} \approx 7.7$ Hz, 1 H, 7-H), 7.54 (d, $^3J_{9\text{-}H,8\text{-}H}$ = 7.3 Hz, 1 H, 9-H), 7.62 (d, $^3J_{4\text{-}H,3\text{-}H}$ = 7.7 Hz, 1 H, 4-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 85.2 (C-4b), 87.6 (C-9b), 111.0 (C-6), 114.4 (C-1), 114.7 (C-2), 118.4 (CN), 121.7 (C-8), 123.4 (C-9a), 125.3 (C-3), 126.6 (C-9), 127.5 (C-4), 129.8 (C-4a), 131.8 (C-7), 159.8 (C-5a), 160.0 (C-10a) ppm. MS (EI): *m*/*z* (%) = 235 (100) $[M]^+$, 206 (55), 178 (9), 151 (10). HRMS (EI): calcd. for $C_{15}H_9NO_2$ $[M]^+$ 235.0628; found 235.0629.

(4b*RS*,9b*RS*)-3-Chloro-4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-5e): (1*RS*,2*RS*)-1-(2-Bromo-5-chlorophenyl)-2-(2-bromophenyl)ethane-1,2-diol (*rac-syn*-**4g**; 816 mg, 2.0 mmol), Cu^{II} oxinate (70 mg, 0.2 mmol), KI (331 mg, 2.0 mmol), and K_3PO_4 (1.70 g, 8.0 mmol) were used according to general procedure IV. Flash chromatography over silica gel (petroleum ether/dichloromethane, 7:3) gave (4b*RS*,9b*RS*)-3-chloro-4b,9b-dihydrobenzofuro[3,2-*b*]-benzofuran (*rac-cis*-**5e**; 396 mg, 1.62 mmol, 81%) as a colorless solid. R_f = 0.40 (petroleum ether/dichloromethane, 7:3), m.p. 137–139 °C. IR: $\tilde{\nu}$ = 3046, 1599, 1477, 1426, 1320, 1275, 1238, 1223, 1167, 1117, 1099, 1073, 1014, 975, 952, 935, 900, 880, 864, 846, 814, 793, 774, 744, 726, 680, 617, 596, 572, 511, 449, 417 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 290 (3.67), 221 (4.11) nm. ^1H NMR (500 MHz, $CDCl_3$): δ = 6.24 (d, $^3J_{4b\text{-}H,9b\text{-}H}$ = 7.5 Hz, 1 H, 4b-H), 6.33 (d, $^3J_{9b\text{-}H,4b\text{-}H}$ = 7.4 Hz, 1 H, 9b-H), 6.88 (br. d, $^3J_{6\text{-}H,7\text{-}H}$ = 8.2 Hz, 1 H, 6-H), 6.97 (d, $^3J_{1\text{-}H,2\text{-}H}$ = 8.6 Hz, 1 H, 1-H), 6.99 (ddd, $^3J_{8\text{-}H,7\text{-}H} \approx 7.5$, $^3J_{8\text{-}H,9\text{-}H} \approx 7.5$ Hz, $^4J_{8\text{-}H,6\text{-}H}$ = 1.0 Hz, 1 H, 8-H), 7.22 (dd, $^3J_{2\text{-}H,1\text{-}H}$ = 8.6, $^4J_{2\text{-}H,4\text{-}H}$ = 2.3 Hz, 1 H, 2-H), 7.29 (ddd, $^3J_{7\text{-}H,6\text{-}H}$ = 8.7, $^3J_{7\text{-}H,8\text{-}H}$ = 7.7 Hz, $^4J_{7\text{-}H,9\text{-}H}$ = 1.5 Hz, 1 H, 7-H), 7.49 (d, $^4J_{4\text{-}H,2\text{-}H}$ = 2.4 Hz, 1 H, 4-H), 7.52 (ddd, $^3J_{9\text{-}H,8\text{-}H}$ = 7.6, $2\times J \approx 0.7$ Hz, 1 H, 9-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 85.8 (C-4b), 87.3 (C-9b), 110.9 (C-6), 111.9 (C-1), 121.4 (C-8), 124.0 (C-9a), 125.8 (C-3 or C-4a), 126.2 (C-3 or C-4a), 126.52 (C-4 or C-9), 126.53 (C-4 or C-9), 131.3 (C-2), 131.6 (C-7), 158.7 (C-10a), 159.9 (C-5a) ppm. MS (EI, 70 eV): *m*/*z* (%) = 244 (100) $[M]^+$, 215 (50), 209 (9), 181 (58), 152 (47), 126 (9), 76 (22), 63 (16). HRMS (EI): calcd. for $C_{14}H_9ClO_2$ $[M]^+$ 244.0286; found 244.0286.

(4b*RS*,9b*RS*)-3,8-Dichloro-4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-5f):[11i] (1*RS*,2*RS*)-1,2-Bis(2-bromo-5-chlorophenyl)ethane-1,2-diol (*rac-syn*-**4h**; 882 mg, 2.0 mmol), Cu^{II} oxinate (70 mg, 0.2 mmol), KI (331 mg, 2.0 mmol), and K_3PO_4 (1.70 g, 8.0 mmol) were used according to general procedure IV. Flash chromatography over silica gel (petroleum ether/dichloromethane, 1:1) gave (4b*RS*,9b*RS*)-3,8-dichloro-4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-**5f**; 430 mg, 1.54 mmol, 77%) as a colorless solid. R_f = 0.4 (petroleum ether/dichloromethane, 1:1), m.p. 256–259 °C (ref.[11i] m.p. 248–250 °C). IR: $\tilde{\nu}$ = 1601, 1478, 1426, 1320, 1167, 1117, 1072, 1031, 950, 814, 785, 745, 726, 693, 597, 576, 535, 516, 454, 427, 399 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 292 (3.59), 227 (4.21) nm. ^1H NMR (300 MHz, $CDCl_3$): δ = 6.28 (s, 2 H, 4b-H and 9b-H), 6.80 (d, $^3J_{1\text{-}H,2\text{-}H} = {}^3J_{6\text{-}H,7\text{-}H}$ = 8.7 Hz, 2 H, 1-H and 6-H), 7.24 (dd, $^3J_{2\text{-}H,1\text{-}H} = {}^3J_{7\text{-}H,6\text{-}H}$ = 8.5, $^4J_{2\text{-}H,4\text{-}H} = {}^4J_{7\text{-}H,9\text{-}H}$ = 2.3 Hz, 2 H, 2-H and 7-H), 7.48 (d, $^4J_{4\text{-}H,2\text{-}H} = {}^4J_{9\text{-}H,7\text{-}H}$ = 2.3 Hz, 2 H, 4-H and 9-H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 86.6 (C-4b and C-9b), 112.0 (C-1 and C-4), 125.8 (C-3 and C-8), 126.1 (C-4a and C-9a), 126.5 (C-4 and C-9), 131.5 (C-2 and C-7), 158.5 (C-5a and C-10a) ppm. MS (EI): *m*/*z* (%) = 278 (100) $[M]^+$, 249 (25), 243 (61), 215 (89), 208 (9), 186 (8), 152 (53), 139 (20), 126 (7), 108 (14), 93 (11), 75 (15), 63 (11).

(4b*RS*,9b*RS*)-3-Fluoro-4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-5g): (1*RS*,2*RS*)-1-(2-Bromo-5-fluorophenyl)-2-(2-bromophenyl)ethane-1,2-diol (*rac-syn*-**4i**; 780 mg, 2.0 mmol), Cu^{II} oxinate (70 mg, 0.2 mmol), KI (331 mg, 2.0 mmol), and K_3PO_4 (1.70 g, 8.0 mmol) were used according to general procedure IV. Flash chromatography over silica gel (petroleum ether/dichloromethane, 7:3) gave (4b*RS*,9b*RS*)-3-fluoro-4b,9b-dihydrobenzofuro[3,2-*b*]-benzofuran (*rac-cis*-**5g**; 370 mg, 1.62 mmol, 81%) as a colorless solid. R_f = 0.25 (petroleum ether/dichloromethane, 7:3), m.p. 147–149 °C. IR: $\tilde{\nu}$ = 1597, 1482, 1326, 1237, 1214, 1175, 1128, 963, 934, 876, 812, 781, 744, 582, 513, 472, 427, 401 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 289 (3.75), 204 (4.51) nm. ^1H NMR (500 MHz, $CDCl_3$): δ = 6.25 (d, $^3J_{4b\text{-}H,9b\text{-}H}$ = 7.5 Hz, 1 H, 4b-H), 6.33 (d, $^3J_{9b\text{-}H,4b\text{-}H}$ = 7.4 Hz, 1 H, 9b-H), 6.78 (dd, $^3J_{1\text{-}H,2\text{-}H}$ = 8.8, $^4J_{1\text{-}H,3\text{-}F}$ = 4.0 Hz, 1 H, 1-H), 6.88 (d, $^3J_{6\text{-}H,7\text{-}H}$ = 8.2 Hz, 1 H, 6-H), 6.97 (ddd, overlapped, $^3J_{2\text{-}H,1\text{-}H} \approx 8.8$, $^3J_{2\text{-}H,3\text{-}F} \approx 8.8$ Hz, $^4J_{2\text{-}H,4\text{-}H}$ = 2.8 Hz, 1 H, 2-H), 6.99 (ddd, overlapped, $^3J_{8\text{-}H,7\text{-}H} \approx 7.5$, $^3J_{8\text{-}H,9\text{-}H} \approx 7.5$ Hz, $^4J_{8\text{-}H,6\text{-}H}$ = 1.0 Hz, 1 H, 8-H), 7.22 (dd, $^3J_{4\text{-}H,3\text{-}F}$ = 7.7, $^4J_{4\text{-}H,2\text{-}H}$ = 2.9 Hz, 1 H, 4-H), 7.29 (ddd, $^3J_{7\text{-}H,6\text{-}H} \approx 7.8$, $^3J_{7\text{-}H,8\text{-}H} \approx 7.8$ Hz, $^4J_{7\text{-}H,9\text{-}H}$ = 1.4 Hz, 1 H, 7-H), 7.52 (d, $^3J_{9\text{-}H,8\text{-}H}$ = 7.5 Hz, 1 H, 9-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 86.2 (C-4b), 87.2 (C-9b), 110.9 (C-6), 111.3 (d, $^3J_{C,F}$ = 8.4 Hz, C-1), 113.0 (d, $^2J_{C,F}$ = 24.6 Hz, C-4), 118.1 (d, $^2J_{C,F}$ = 24.5 Hz, C-2), 121.4 (C-8), 124.2 (C-9a), 125.4 (d, $^2J_{C,F}$ = 8.6 Hz, C-4a), 126.5 (C-9), 131.5 (C-7), 156.0 (d, $^4J_{C,F}$ = 1.4 Hz, C-10a), 157.4 (d, $J_{C,F}$ = 238.6 Hz, C-3), 159.9 (C-5a) ppm. MS (EI): *m*/*z* (%) = 228 (100) $[M]^+$, 199 (74), 181 (4), 170 (12). HRMS (EI): calcd. for $C_{14}H_9FO_2$ $[M]^+$ 228.0581; found 228.0584.

(2*RS*,3*RS*)-2-(2-Bromophenyl)-2,3-dihydrobenzofuran-3-ol (*rac-cis*-6a): (1*RS*,2*RS*)-1,2-Bis(2-bromophenyl)ethane-1,2-diol (*rac-syn*-**4a**; 746 mg, 2.0 mmol), Cu^{II} oxinate (69 mg, 0.2 mmol), KI (334 mg, 2.0 mmol), and K_3PO_4 (427 mg, 2.0 mmol) were used according to general procedure IV. After work up, (4b*RS*,9b*RS*)-4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-**5a**; 67 mg, 0.32 mmol, 16%) was isolated along with (2*RS*,3*RS*)-2-(2-bromophenyl)-2,3-dihydrobenzofuran-3-ol (*rac-cis*-**6a**; 152 mg, 0.52 mmol, 26%). Data for *rac-cis*-**6a**: R_f = 0.14 (petroleum ether/dichloromethane, 7:3), m.p. 122–123 °C. IR: $\tilde{\nu}$ = 3480, 2962, 1599, 1567, 1476, 1463, 1436, 1410, 1306, 1264, 1227, 1176, 1150, 1109, 1049, 1027, 1014, 969, 920, 866, 832, 773, 746, 700, 675, 627, 614, 573, 498, 464, 433 cm^{-1}. UV (CH_3CN): λ_{max} ($\log\varepsilon$) = 279 (3.47), 211 (3.94) nm. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.41 (d, $^3J_{OH,3\text{-}H}$ = 6.9 Hz, 1 H, OH), 5.65 (dd, $^3J_{3\text{-}H,OH} \approx 6.5$, $^3J_{3\text{-}H,2\text{-}H} \approx 6.5$ Hz, 1 H, 3-H), 5.86 (d, $^3J_{2\text{-}H,3\text{-}H}$ = 6.2 Hz, 1 H, 2-H), 7.02 (ddd, overlapped, $^3J_{5\text{-}H,4\text{-}H} \approx 7.4$, $^3J_{5\text{-}H,6\text{-}H} \approx 7.4$ Hz, $^4J_{5\text{-}H,7\text{-}H}$ = 0.7 Hz, 1 H, 5-H), 7.02 (d, overlapped, $^3J_{7\text{-}H,6\text{-}H}$ = 8.1 Hz, 1 H, 7-H), 7.24 (ddd, $^3J_{4'\text{-}H,3'\text{-}H} \approx 7.8$, $^3J_{4'\text{-}H,5'\text{-}H} \approx 7.8$ Hz, $^4J_{4'\text{-}H,6'\text{-}H}$ = 1.6 Hz, 1 H, 4′-H), 7.34 (ddd, $^3J_{6\text{-}H,5\text{-}H} \approx 7.9$, $^3J_{6\text{-}H,7\text{-}H} \approx 7.9$ Hz, $^4J_{6\text{-}H,4\text{-}H}$ = 1.3 Hz, 1 H, 6-H), 7.38 (ddd, $^3J_{5'\text{-}H,6'\text{-}H} \approx 7.4$, $^3J_{5'\text{-}H,4'\text{-}H} \approx 7.4$ Hz, $^3J_{5'\text{-}H,3'\text{-}H}$ = 1.0 Hz, 1 H, 5′-H), 7.48 (dd, $^3J_{4\text{-}H,5\text{-}H}$ = 7.5, $^4J_{4\text{-}H,6\text{-}H}$ = 1.3 Hz, 1 H, 4-H), 7.63 (dd, $^3J_{3'\text{-}H,4'\text{-}H}$ = 7.9, $^4J_{3'\text{-}H,5'\text{-}H}$ = 1.1 Hz, 1 H, 3′-H), 7.65 (dd, $^3J_{6'\text{-}H,5'\text{-}H}$ = 7.4, $^4J_{6'\text{-}H,4'\text{-}H}$ = 1.4 Hz, 1 H, 6′-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 71.8 (C-3), 87.5 (C-2), 110.6 (C-7), 121.56 (C-2′), 121.58 (C-5), 126.3 (C-4), 127.5 (C-5′), 127.9 (C-3a), 128.7 (C-6′), 129.7 (C-4′), 130.9 (C-6), 132.5 (C-3′), 135.1 (C-1′), 159.5 (C-7a) ppm. MS (EI): *m*/*z* (%) = 290 (39) $[M]^+$, 272 (100), 261 (33), 169 (46), 165 (70), 121 (81), 97 (33), 71 (41), 57 (65). HRMS (EI): calcd. for $C_{14}H_{11}BrO_2$ $[M]^+$ 289.9937; found 289.9950.

(2*RS*,3*SR*)-2-(2-Bromophenyl)-2,3-dihydrobenzofuran-3-ol (*rac-trans*-6a): (1*RS*,2*SR*)-1,2-Bis(2-bromophenyl)ethane-1,2-diol (*meso*-**4a**; 742 mg, 2.0 mmol), Cu^{II} oxinate (69 mg, 0.2 mmol), KI (334 mg, 2.0 mmol), and K_3PO_4 (1.70 g, 8.0 mmol) were used according to general procedure IV. Crystallization from dichloromethane/petroleum ether gave (2*RS*,3*SR*)-2-(2-bromophenyl)-2,3-dihydrobenzofuran-3-ol (*rac-trans*-**6a**; 266 mg, 0.92 mmol, 46%) as a colorless solid. R_f = 0.13 (petroleum ether/dichloromethane, 7:3), m.p. 106–107 °C. IR: $\tilde{\nu}$ = 3238, 1599, 1568, 1474, 1464, 1439, 1313, 1291, 1256, 1234, 1164, 1120, 1099, 1036, 1013, 1000, 967, 878, 844, 811, 746, 682, 638, 605, 573, 534, 485, 448 cm^{-1}. UV (CH_3CN): λ_{max} (logε) = 287 (3.65), 280 (3.66), 218 (4.17), 213 (4.196) nm. ^1H NMR (500 MHz, $CDCl_3$): δ = 2.47 (s, 1 H, OH), 5.22 (d, $^3J_{3\text{-H},2\text{-H}}$ = 1.7 Hz, 1 H, 3-H), 5.87 (d, $^3J_{2\text{-H},3\text{-H}}$ = 2.1 Hz, 1 H, 2-H), 6.99 (ddd, $^3J_{5\text{-H},4\text{-H}} \approx 7.5$, $^3J_{5\text{-H},6\text{-H}} \approx 7.5$ Hz, $^4J_{5\text{-H},7\text{-H}}$ = 1.0 Hz, 1 H, 5-H), 7.05 (dd, $^3J_{7\text{-H},6\text{-H}}$ = 7.0, $^4J_{7\text{-H},5\text{-H}}$ = 0.7 Hz, 1 H, 7-H), 7.16–7.19 (m, 1 H, 4′-H), 7.21–7.24 (m, overlapped, 2 H, 5′-H and 6′-H), 7.35 (ddd, $^3J_{6\text{-H},5\text{-H}} \approx 7.6$, $^3J_{6\text{-H},7\text{-H}} \approx 7.6$ Hz, $^4J_{6\text{-H},4\text{-H}}$ = 1.5 Hz, 1 H, 6-H), 7.38 (ddd, $^3J_{4\text{-H},5\text{-H}}$ = 7.5, $2\times J \approx 0.7$ Hz, 1 H, 4-H), 7.61 (ddd, $^3J_{3'\text{-H},4'\text{-H}}$ = 7.8, $2\times J \approx 0.8$ Hz, 1 H, 3′-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 79.3 (C-3), 90.9 (C-2), 110.4 (C-7), 121.67 (C-2′), 121.70 (C-5), 126.2 (C-4), 126.3 (C-3a), 126.5 (C-6′), 127.6 (C-5′), 129.3 (C-4′), 131.2 (C-6), 133.02 (C-3′) 138.0 (C-1′), 160.4 (C-7a) ppm. MS (EI): *m*/*z* (%) = 290 (50) $[M]^+$, 272 (31), 261 (25), 169 (63), 165 (58), 121 (100), 105 (17), 77 (24). HRMS (EI): calcd. for $C_{14}H_{11}BrO_2$ $[M]^+$ 289.9937; found 289.9942.

(2*RS*,3*RS*)-2-(2-Chlorophenyl)-2,3-dihydrobenzofuran-3-ol (*rac-cis*-6b): (1*RS*,2*RS*)-1-(2-Bromophenyl)-2-(2-chlorophenyl)ethane-1,2-diol (*rac-syn*-**4c**; 495 mg, 2.0 mmol), Cu^{II} oxinate (70 mg, 0.2 mmol), KI (331 mg, 2.0 mmol), and K_3PO_4 (1.70 g, 8.0 mmol) were used according to general procedure IV. Flash chromatography over silica gel (petroleum ether/dichloromethane, 1:1) gave (2*RS*,3*RS*)-2-(2-chlorophenyl)-2,3-dihydrobenzofuran-3-ol (*rac-cis*-**6b**; (336 mg, 1.36 mmol, 68%) as a colorless solid, and (4b*RS*,9b*RS*)-4b,9b-dihydrobenzofuro[3,2-*b*]benzofuran (*rac-cis*-**5a**; 19 mg, 0.09 mmol, 5%). Data for *rac-cis*-**6b**: R_f = 0.18 (petroleum ether/dichloromethane, 1:1), m.p. 118–119 °C. IR: $\tilde{\nu}$ = 3414, 3052, 1599, 1574, 1475, 1466, 1442, 1273, 1229, 1179, 1149, 1128, 1107, 1052, 1035, 1015, 985, 935, 873, 832, 775, 745, 700, 634, 615, 575, 561, 474, 438, 417 cm^{-1}. UV (CH_3CN): λ_{max} (logε) = 293 (3.44), 222 (4.47) nm. ^1H NMR (500 MHz, $CDCl_3$): δ = 1.39 (d, $^3J_{OH,3\text{-H}}$ = 6.6 Hz, 1 H, OH), 5.61 (dd, $^3J_{OH,3\text{-H}} \approx 6.5$, $^3J_{3\text{-H},2\text{-H}} \approx 6.5$ Hz, 1 H, 3-H), 5.89 (d, $^3J_{2\text{-H},3\text{-H}}$ = 6.2 Hz, 1 H, 2-H), 7.01 (ddd, overlapped, $^3J_{5\text{-H},4\text{-H}} \approx 7.5$, $^3J_{5\text{-H},6\text{-H}} \approx 7.5$ Hz, $^4J_{5\text{-H},7\text{-H}}$ = 1.0 Hz, 1 H, 5-H), 7.02 (d, overlapped, $^3J_{7\text{-H},6\text{-H}}$ = 7.8 Hz, 1 H, 7-H), 7.29–7.36 (m, 3 H, 6-H, 5′-H and 4′-H), 7.45 (dd, $^3J_{3'\text{-H},4'\text{-H}}$ = 7.4, $^4J_{3'\text{-H},5'\text{-H}}$ = 1.8 Hz, 1 H, 3′-H), 7.48 (dm, $^3J_{4\text{-H},4\text{-H}}$ = 7.7, $^3J_{4\text{-H},5\text{-H}}$ = 7.7 Hz, 1 H, 4-H), 7.67 (dd, $^3J_{6'\text{-H},5'\text{-H}}$ = 7.3, $^4J_{6'\text{-H},4'\text{-H}}$ = 2.1 Hz, 1 H, 6′-H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ = 72.0 (C-3), 85.8 (C-2), 110.6 (C-7) 121.6 (C-5), 126.3 (C-4), 127.0 (C-5), 128.0 (C-3a), 128.3 (C-6′), 129.29 (C-3′ or C-4′), 129.34 (C-3′ or C-4′), 130.9 (C-6), 131.7 (C-2′), 133.5 (C-1′), 159.5 (C-7a) ppm. MS (EI): *m*/*z* (%) = 246 (92), 217 (52), 183 (20), 165 (16), 152 (6), 139 (11), 121 (100), 105 (17), 89 (8). HRMS (EI): calcd. for $C_{14}H_{11}ClO_2$ $[M]^+$ 246.0448; found 246.0451.

Supporting Information (see footnote on the first page of this article): ^1H and ^{13}C NMR spectra for compounds **2a**–**2i**, **4a**–**4i**, **5a**–**5g**, **6a**, and **6b**; computational studies on compound *rac-cis*-**5e**.

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[21] a) The enantiomeric purity of (+)-*syn*-**4a** was determined from its optical rotation (see Exp. Sect.). b) The enantiomeric purity was determined by chiral HPLC (CHIRALPAK IB column; 250 mm × 4.6 mm; 5 μm; *n*-hexane/2-propanol, 96:4; flow rate of 1 mL/min; UV detection: λ = 280 nm).

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