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A Two-Step, Three-Component Queuing Cascade Leading to Dihydrobenzoxepine and Dihydrobenzazepine Derivatives[‡]

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Dedicated to Professor Waldemar Adam on the occasion of his 60th birthday

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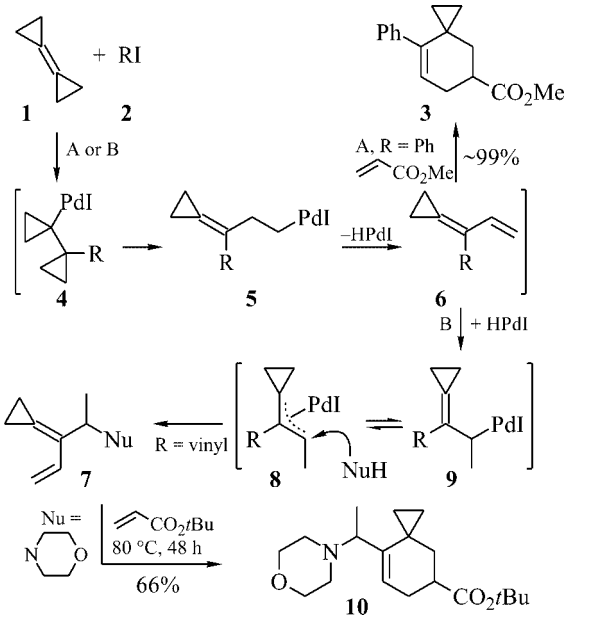
A palladium-catalyzed reaction of methylenespiropentane (**11**) with iodobenzene (**12**) under typical Heck conditions [$Pd(OAc)_2$, PPh_3, Et_3N, DMF] produced a mixture of the unstable [3]dendralene **13** and allylidenecyclopropane **14** in 38 % yield. When an analogous reaction with iodobenzene was carried out in the presence of morpholine (**25**) and of tris(2-furyl)phosphane (TFP) instead of triphenylphosphane, the dienes **26**, **28** and **31** were generated by nucleophilic trapping of π-allylpalladium intermediates **30** and **32**. The cross coupling of methylenespiropentane (**11**) with the functionalized aryl iodides **33a–g** in the presence of a palladium precatalyst [$Pd(OAc)_2$, TFP, Et_3N, DMF] at 80 °C, 3 h, provided the seven-membered 3,4-dimethylene-substituted heterocycles **34a–g** and **35b** which, upon addition of dimethyl fumarate (**19**), underwent Diels–Alder reactions to furnish bicyclic and higher oligocyclic dihydrobenzoxepine and -benzazepine derivatives **36a–g** and **37b**, yet in rather moderate yields of 18–29 % only. The overall process constitutes a one-pot, two-step, three-component queuing cascade.

Introduction

The highly strained and thereby unusually reactive tetrasubstituted alkene bicyclopropylidene (**1**), which can easily be prepared on a multigram scale,[1] has been turned into a versatile C_6 building block for various synthetic applications.[2] It is particularly remarkable that the double bond in bicyclopropylidene (**1**) undergoes exceptionally fast carbopalladations in Heck-type reactions.[3] These coupling reactions with various aryl and alkenyl iodides can be carried out in the presence of a dienophile such as methyl acrylate and, in a sequence of carbopalladation across the double bond in **1**, cyclopropylmethyl- to homoallylpalladium rearrangement, β-dehydropalladation and [4+2] cycloaddition of the thus formed allylidenecyclopropanes, yield the spiro[2.5]octene derivatives **3** in a single operation (Scheme 1).[3b] Under slightly modified conditions, i.e. in the presence of tris(2-furyl)phosphane (TFP) instead of tri-



Scheme 1. Two recently developed one-pot reactions of bicyclopropylidene (**1**) involving palladium-catalyzed Heck couplings, cyclopropylcarbinyl to homoallyl rearrangements, β-dehydropalladations, rehydridopalladation and Diels–Alder reactions. (A) $Pd(OAc)_2$, PPh_3, Et_4NCl, K_2CO_3, Me_3CN, 80 °C, 48 h. (B) $Pd(OAc)_2$, TFP, Et_3N, DMF, 80 °C, 2 h.

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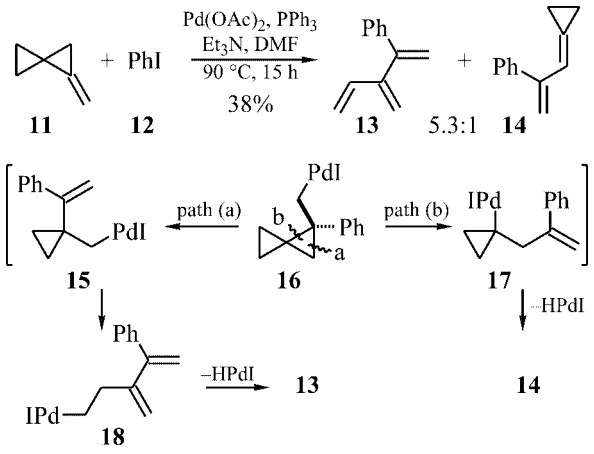
phenylphosphane, the initial products of type **6** undergo rehydridopalladation with reverse regioselectivity to yield the π-allylpalladium complexes **8** which are trapped by nucleophiles, e.g. morpholine, in a regioselective manner. When the coupling partner is a vinyl iodide, such coupling-substitution products **7** are also reactive 1,3-dienes, and thus can undergo [4+2] cycloadditions with, e.g., added *tert*-butyl acrylate to furnish the 1-morpholinoethyl-substituted *tert*-butyl spiro[2.5]octenecarboxylate **10**. Methylenespiropentane (**11**), the strain energy (74.6 kcal/mol) of which is only 2.8 kcal/mol lower than that of bicyclopropylidene (**1**),[5] would be expected to undergo similarly rapid carbopalladations and subsequent rearrangements as **1** does. Because methylenespiropentane (**11**) is easily available on a multigram scale by thermal rearrangement of **1**,[4] we set out to explore palladium-catalyzed cross couplings of **11** with aryl iodides and possible subsequent transformations of the products.

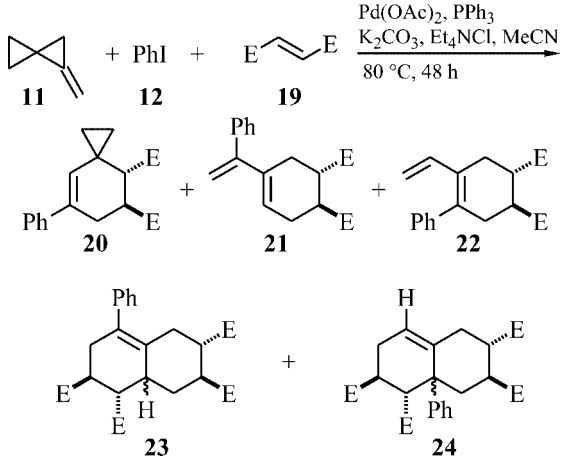
Results and Discussion

An initially performed coupling of methylenespiropentane (**11**) with iodobenzene (**12**) under usual Heck conditions [$Pd(OAc)_2$, PPh_3, Et_3N] in DMF at 90 °C after 15 h gave a mixture of the cross-conjugated triene ([3]dendralene) **13** and (2-phenylallylidene)cyclopropane (**14**) (ratio 5.3:1.0) as an unstable oil in 38% yield. All attempted tuning of the reaction conditions did not lead to increased yields and/or selectivities. The formation of the two products **13** and **14** can be rationalized as arising from the cleavage of the two different proximal bonds [(a) and (b)] in the cyclopropane ring adjacent to the iodopalladiummethyl group in the intermediate **16** arising upon carbopalladation of the double bond in **11** by the initially formed phenylpalladium iodide. The σ-homoallylpalladium species **15** formed along path (a) undergoes another cyclopropylcarbinyl-to-homoallyl rearrangement, and subsequent β-dehydropalladation in the thus formed homoallylpalladium intermediate **18** leads to the conjugated triene **13**. On the other hand, the σ-homoallylpalladium complex **17** stemming from cleavage of the proximal bond (b) in **16** undergoes an immediate β-hydride elimination to produce the diene **14** (Scheme 2).



Scheme 2. Heck coupling of methylenespiropentane (**11**) with iodobenzene (**12**).

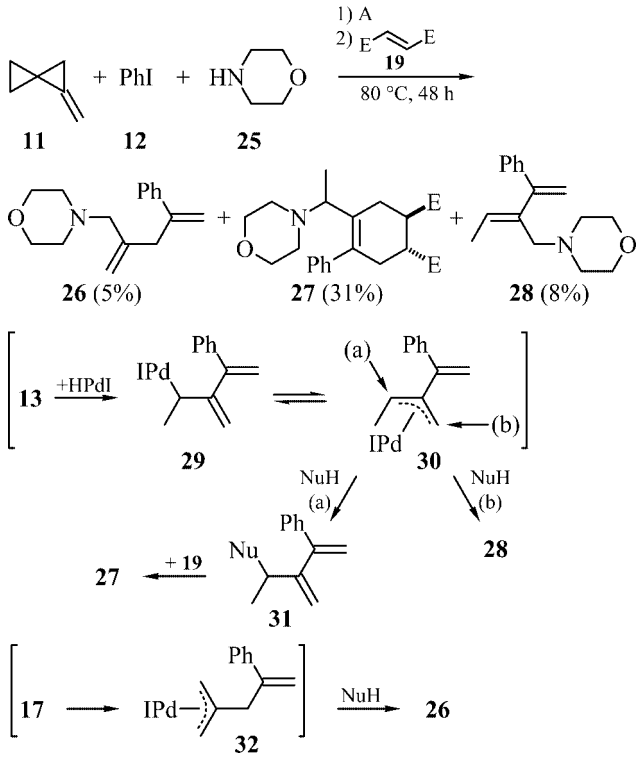
This reaction essentially represents another novel access to [3]dendralenes and allylidenecyclopropanes, yet in low yields. Because this is at least partly due to the susceptibility of both compounds[6,7] to undergo polymerization, cycloadducts or other consecutive products might be obtained in better yields if the compounds **13** and **14** were trapped directly upon formation, as previously demonstrated for the regioisomer of **14** formed in the Heck cross coupling of bicyclopropylidene (**1**) with iodobenzene.[3c] Thus, methylenespiropentane (**11**) and iodobenzene (**12**) in the presence of dimethyl fumarate (**19**) were treated with a palladium precatalyst system [$Pd(OAc)_2$, PPh_3, Et_4NCl, K_2CO_3, Me_3CN] that previously had given the best results in such domino processes with bicyclopropylidene (**1**) (Scheme 3).[3b] However, with **11** this reaction always produced inseparable mixtures that contained the Diels–Alder product **20** stemming from **14** as well as the two regioisomeric monocycloadducts **21**, **22** and several diastereomers of the regioisomeric transmissive cycloadducts **23**, **24** arising from the cross-conjugated triene **13**. In addition, the yields were low, and thus the different products could not be fully characterized.



Scheme 3. A domino Heck–Diels–Alder reaction involving methylenespiropentane (**11**), iodobenzene (**12**) and dimethyl fumarate (**19**). E = CO_2Me.

In order to particularly trap the product stemming from the major intermediate **18** of the carbopalladation/rearrangement sequence more efficiently, the reaction of **11** with **12** was carried out in the presence of tris(2-furyl)phosphane (TFP). The latter is known from previous work[3b,3f] to stimulate the formation of π-allylpalladium complexes, which would be captured by an added nucleophile such as morpholine (**25**) to furnish more stable dienes **26**, **28** and **31** instead of the cross-conjugated triene **13** and allylidenecylopropane **14**. In order to prevent Michael addition of the nucleophile onto the dienophile, the latter should not be present in the reaction mixture from the beginning. Indeed, treatment of **11**, **12** and morpholine (**25**) in DMF with the palladium precatalyst established for such transformations

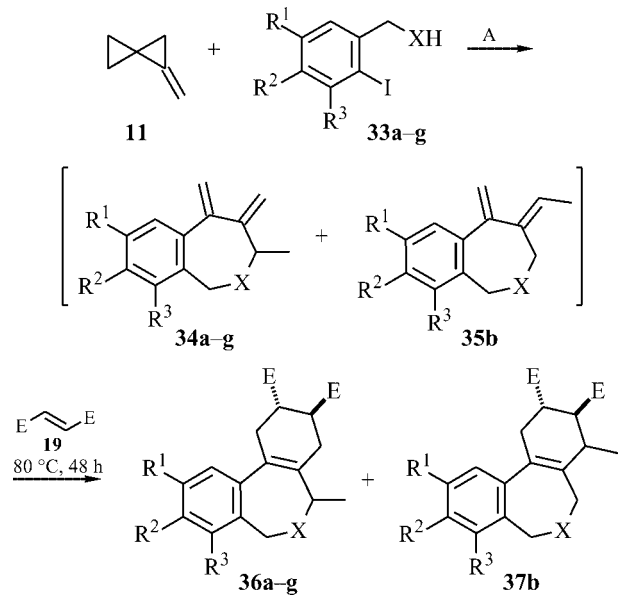
[$Pd(OAc)_2$, TFP, Et_3N][3b] at 80 °C for 3 h, then addition of dimethyl fumarate (**19**) and subsequent heating of the mixture at 80 °C for 48 h, led to the three separable products[3f] **26**, (5% yield), **27** (39%) and **28** (8%) (Scheme 4).



Scheme 4. One-pot palladium-catalyzed reaction of methylenespiropentane (**11**) with iodobenzene (**12**) and morpholine (**25**) with subsequent trapping of a formed 1,3-diene by dimethyl fumarate (**19**). (A) $Pd(OAc)_2$, TFP, Et_3N, DMF, 80 °C, 3 h. NuH = morpholine. E = CO_2Me.

Apparently, the σ-allylpalladium intermediate **29** formed by preferred regioselective readdition of the hydridopalladium species onto the terminal vinyl group in **13**, which is in an equilibrium with the π-allylpalladium intermediate **30**, is predominantly attacked by morpholine (**25**) at the more highly substituted site to give the diene **31** as the major product, and the latter undergoes a cycloaddition with dimethyl fumarate (**19**) to yield the cyclohexene derivative **27**. The minor conjugated diene **28**, stemming from the same π-allylpalladium intermediate **30**, due to its 1,2,3-trisubstitution obviously is less reactive, and the non-conjugated diene **26**, arising along path (b) with subsequent ring opening of the cyclopropylpalladium iodide moiety in **17** to a π-allylpalladium intermediate **32** and its trapping by **25**, cannot react with the dienophile **19**.

More interesting and relevant types of products were obtained, when *o*-iodobenzyl alcohols and -amines **33a**–**g** were employed in this two-step, one-pot reaction (Scheme 5, Table 1). The intramolecular nucleophilic trapping of the π-allylpalladium intermediate of type **30** in this case occurred almost exclusively at the more highly substituted end of the allyl moiety to yield 5,6-benzo-3,4-dimethylenetetrahydrooxepines and -azepines. **34a**–**g** which underwent subsequent [4+2] cycloaddition with added dimethyl fumarate (**19**) to furnish dihydrobenzoxepine and dihydrobenzazepine derivatives **36a**–**g**. The structure of **36c** was rigorously proved by X-ray diffractometry (Figure 1),[8] those of the others were assigned on the basis of their analogous NMR spectroscopic data.



Scheme 5. One-pot, two-step, three-component queuing cascade involving methylenespiropentane (**11**). *o*-iodobenzyl alcohols and -amines **33a**–**g** as well as dimethyl fumarate (**19**). (A) $Pd(OAc)_2$, TFP, Et_3N, DMF, 80 °C, 3 h. E = CO_2Me. For details see Table 1.

Table 1. One-pot, two-step, three component queuing cascade involving methylenespiropentane (**11**), *o*-iodobenzyl alcohols and -amines **33a**–**g** as well as dimethyl fumarate (**19**) (see Scheme 5).

Aryl iodide	R^1	R^2	R^3	X	Product	Yield (%)[a]	*dr*[b]
33a	H	H	H	O	**36a**	22	1:1
33b	H	H	H	NBn	**36b** + **37b**	22 + 5	1.6:1[c]
33c	OMe	OMe	H	O	**36c**	18	1.6:1
33d	–OCH_2O–		H	O	**36d**	21	1:1
33e	–OCH_2O–		H	NBn	**36e**	20	1.5:1
33f	–$O(CH_2)_2O$–		H	O	**36f**	23	1.1:1
33g	H	–OCH_2O–		O	**36g**	29	1.1:1

[a] Isolated yields. [b] Diastereomeric ratios were determined by integration of relevant ^1H NMR signals in the spectra of the crude products. [c] Diastereomeric ratio of the benzazepine derivative **36b**.

Only in one case (Entry 2, Table 1) was an isomeric dihydrobenzazepine derivative **37b** with the methyl substituent on the cyclohexene ring isolated in 5% yield as a single diastereomer in addition to 22% of two diastereomeric products **36b**. The isomer **37b** must originate from the isomeric diene **35b** which must have been formed by nucleophilic attack of the benzylamino group at the non-substituted terminus of the π-allylpalladium intermediate of type **30** [path (b) in Scheme 4]. In none of the other examples was any of this type of reaction mode detected as the spectra of the crude products did not indicate even traces of products of type **37b**.

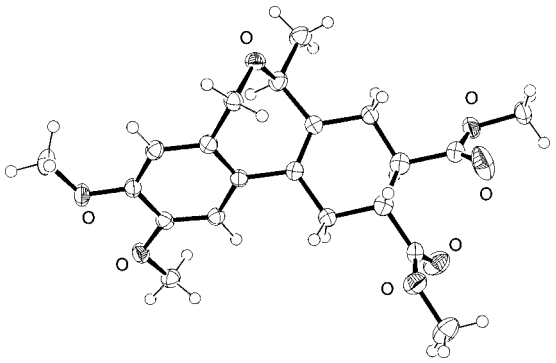
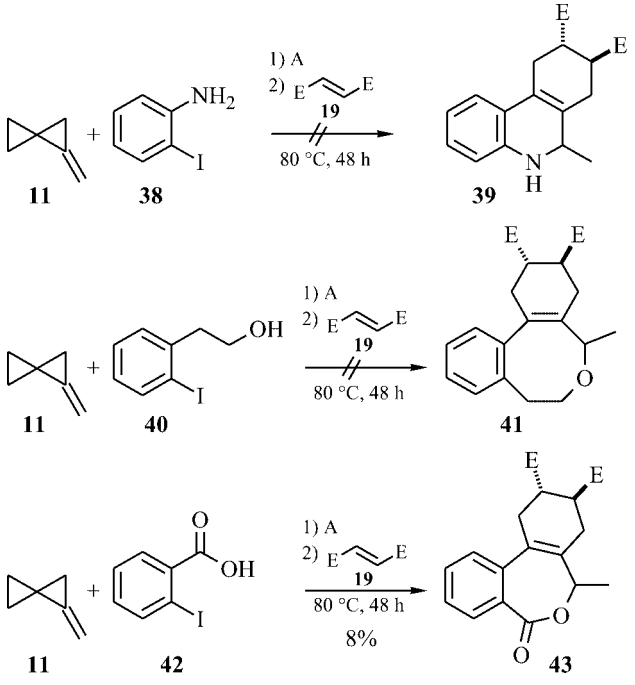


Figure 1. Structure of compound **36c** (major diastereomer) in the crystal.[8] $C_{21}H_{26}O_7$ (390.42); crystal size 0.30 × 0.30 × 0.30 mm; triclinic; a = 727.68(7), b = 1188.90(12), c = 1290.95(12) pm; α = 109.904(7), β = 93.316(8), γ = 106.331(8)°; V = 0.99306(17) nm^3; Z = 2; space group $P\bar{1}$; T = 133(2) K; ρ = 1.306 Mg/m^{-3}; μ = 0.098 mm^{-1}; F_o = 416; θ range for data collection: 1.70–24.79°; reflections collected: 11159; R_{int} = 3356 [0.0370]; data/restraints/parameters: 3356/0/253; Goof on F^2 = 1.115; final R indices [$I > 2\sigma(I)$]: R_1 = 0.0505, wR_2 = 0.1480; R indices (all data): R_1 = 0.0672, wR_2 = 0.1562; largest difference peak/hole: 0.839/–0.314 e Å^{-3}.

Yields were moderate to poor, the best one (29%) was achieved with (5-iodobenzo[1,3]dioxol-4-yl)methanol (**33g**). Inspired by successful literature protocols for palladium-catalyzed annelations involving an intramolecular trapping of π-allylpalladium intermediates,[9] numerous reaction conditions were tried out with the combination of methylenespiropentane (**11**), *o*-iodobenzyl alcohol (**33a**) and dimethyl fumarate (**19**) in order to improve the yields of these new sequential reactions. However, none of the tested conditions in terms of other bases (NaOAc, KOAc, K_2CO_3, Ag_2CO_3, Cs_2CO_3 in the presence of Et_4NCl or nBu_4NCl), other palladium derivatives [$Pd(dba)_2$, $Pd_2(dba)_3$·$CHCl_3$], other temperatures (60, 100, 120 °C) and different reaction times (between 0.5 h and 2 d for the first step) furnished any better yields than 22% of **36a**.



Scheme 6. Attempted syntheses of six- and eight-membered heterocycles **39**, **41** and formation of the benzo-annelated ε-caprolactone derivative **43** from **11**, *o*-iodobenzoic acid and **19**.

An attempted extension of this method to the formation of doubly annelated six- and eight-membered heterocycles was unsuccessful, too. Thus, *o*-iodoaniline (**38**) and 2-iodophenethyl alcohol (**40**) did not yield the desired products **39** and **41**, respectively, at all. However, with *o*-iodobenzoic acid (**42**) as a coupling partner with an internal nucleophilic group, the benzo-annelated ε-caprolactone **43** was produced, albeit in only 8% yield (Scheme 6).

Conclusions

Despite providing generally low yields (18–29%), this new sequential reaction is interesting as it produces valuable doubly fused seven-membered heterocycles (**36a**–**g** and **37b**, **43**), resembling the skeletons of several natural and non-natural biologically active compounds.[10] Moreover, dioxole also often plays an important role in physiologically active molecules.[11] Thus, incorporation of the essential features of benzoxepines and benzazepines in combination with dioxole subunits in **33d**–**g** might provide enhanced biological activities.

Experimental Section

General Remarks: NMR spectra were recorded with Bruker AM 250 (250 MHz for ^{1}H and 62.9 MHz for ^{13}C NMR) and Varian UNITY-300 (300 MHz for ^{1}H and 75.5 MHz for ^{13}C NMR) instruments. Chemical shifts δ are given in ppm relative to residual peaks of deuterated solvents and coupling constants, J, are reported in Hz. The following abbreviations are used to describe spin multiplicities in ^{1}H NMR spectra: s = singlet; bs = broad singlet; d = doublet; t = triplet; q = quartet; dd = doublet of doublets; ddd = doublet of doublets of doublets; dt = doublet of triplets; dq = doublet of quartets; m = multiplets. Multiplicities in ^{13}C NMR spectra were determined by DEPT (Distortionless Enhancement by Polarization Transfer): + = primary or tertiary (positive DEPT signal), – = secondary (negative DEPT Signal), C_{quat} = quaternary carbon atoms or APT (Attached Proton Test) measurements. HMQC (Heteronuclear Multiple Quantum Coherence) spectra were also measured in certain cases. IR spectra were recorded with a Bruker IFS 66 spectrometer and measured as KBr pellets or as oils between KBr plates. Low resolution mass spectra (EI at 70 eV or DCI with NH_3) were obtained with a Finnigan MAT 95 spectrometer. High-resolution mass spectra (HRMS) were obtained with a Finnigan MAT 95 spectrometer by preselected-ion peak matching at $R \approx 10000$ to be within ±2 ppm of the exact masses. Elemental analyses were carried out by the "Mikroanalytisches Laboratorium des Instituts für Organische und Biomolekulare Chemie der Universität Göttingen". Chromatographic separations were performed with Merck Silica 60 (200–400 or 70–230 mesh). The dimensions of the columns are given as "diameter × height of the silica gel column". TLC was performed with Macherey–Nagel TLC Alugram® Sil G/UV 254 plates, detection was under UV light at 254 nm and development with MOPS reagent (10% molybdophosphoric acid in ethanol). All reagents were used as purchased

from commercial suppliers without further purification unless otherwise indicated. Acetonitrile was dried with P_2O_5, DMF and CH_2Cl_2 were distilled from CaH_2. Diethyl ether and THF were freshly distilled from sodium benzophenone ketyl. Solvents for column chromotography, ethyl acetate and light petroleum were distilled in a rotary evaporator. The following compounds were prepared according to known literature methods: methylenespiropentane (**11**),[4] 2,3-dihydrobenzo[1,4]dioxine-6-carbaldehyde,[12] benzo[1,3]dioxole-4-carbaldehyde,[12] (3,4-dimethoxyphenyl)methanol,[13] piperonylic alcohol,[14] (2,3-dihydrobenzo[1,4]dioxin-6-yl)-methanol,[14] (benzo[1,3]dioxol-4-yl)methanol,[15] 2-iodo-4,5-dimethoxybenzyl alcohol (**33c**),[16] (6-iodobenzo[1,3]dioxol-5-yl)-methanol (**33d**),[17] (5-iodobenzo[1,3]dioxol-4-yl)methanol (**33g**),[15] 5-chloromethyl-6-iodobenzo[1,3]dioxole,[18] 2-iodobenzyl methanesulfonate,[19] (benzyl)(2-iodobenzyl)amine (**33b**),[20] 2-(2-iodophenyl)ethanol (**40**).[21]

Heck Reaction of Methylenespiropentane (11) with Iodobenzene (12). 3-Methylene-4-phenyl-1,4-pentadiene (13) and 1-Cyclopropylidene-2-phenylpropene (14): Palladium acetate (22.4 mg, 100 μmol, 10 mol-%) and triphenylphosphane (78.6 mg, 300 μmol, 30 mol-%), were suspended in anhydrous DMF (5 mL) in a screw-cap Pyrex bottle. Argon was bubbled through the mixture for 5 min, and then triethylamine (202 mg, 2.00 mmol), iodobenzene (12, 1.00 mmol, 204 mg) and methylenespiropentane (**11**) (160 mg, 2.00 mmol) were added. After having stirred the mixture at 90 °C for 15 h, the bottle was cooled to ambient temperature. The reaction mixture was taken up in hexane (20 mL), the solution washed with water (15 mL), and the aqueous phase was extracted with hexane (5 × 20 mL). The combined organic phases were dried ($MgSO_4$). After removal of the solvent in a rotary evaporator, the residue was subjected to chromatography on silica gel (2 × 45 cm, hexane) to yield a mixture of **13** and **14** (61 mg, 38%, colorless oil, ratio 5.3:1 according to GC of the crude product). **13:** R_f = 0.5 (hexane). ^{1}H NMR (250 MHz, C_6D_6): δ = 7.07–7.41 (m, 5 H, Ph), 6.35 (dd, J = 10.5, 17.3 Hz, 1 H), 5.42 (d, J = 1.5 Hz, 1 H), 5.21 (d, J = 1.5 Hz, 1 H), 5.14 (d, J = 17.5 Hz, 1 H), 5.14 (dd, J = 1.0, 1.5 Hz, 2 H), 4.95 (d, J = 10.8 Hz, 1 H) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, DEPT): δ = 148.22 (C_{quat}), 147.97 (C_{quat}), 137.27 (+), 128.20 (+), 127.56 (+), 126.71 (+), 118.36 (–), 117.48 (–), 114.86 (–) ppm. **14:** ^{1}H NMR (250 MHz, C_6D_6): δ = 7.07–7.41 (m, 5 H, Ph), 6.71 (dd, J = 2.0, 2.3 Hz, 1 H), 5.33 (s, 1 H), 5.23 (s, 1 H), 0.69–0.97 (m, 4 H) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, DEPT): δ = 147.47 (C_{quat}), 141.17 (C_{quat}), 136.98 (C_{quat}), 127.95 (+), 127.73 (+), 127.14 (+), 119.20 (+), 114.63 (–), 4.77 (–), 1.32 (–) ppm. MS (70 eV, EI): *m*/*z* (%) = 157 (29) [M^+ + 1], 156 (91) [M^+], 155 (87), 154 (14), 153 (25), 152 (13), 144 (9), 143 (18), 142 (18), 141 (100), 130 (12), 129 (53), 128 (71), 127 (20), 115 (74), 105 (12), 103 (16), 102 (15), 91 (33), 89 (8), 86 (10), 84 (15), 82 (8), 78 (12), 77 (35), 76 (10). $C_{12}H_{12}$ (156.2): calcd. 156.0939 (correct HRMS). The purified mixture of isomers **13** and **14** was used for ^{1}H, ^{13}C NMR, and EI-MS and HRMS measurements.

Sequential Heck/Diels–Alder Reaction Involving Methylenespiropentane (11), Iodobenzene (12) and Dimethyl Fumarate (19): A screw-cap Pyrex bottle was charged with anhydrous acetonitrile (1 mL), K_2CO_3 (276 mg, 2.00 mmol) and Et_4NCl (166 mg, 1.00 mmol). Argon was bubbled through the mixture for 5 min, $Pd(OAc)_2$ (11.2 mg, 50 μmol, 5 mol-%), and triphenylphosphane (39.3 mg, 150 μmol, 15 mol-%) were added, and the mixture was stirred once more for an additional 5 min with argon bubbling through, before iodobenzene (**12**, 204 mg, 1.00 mmol), methylenespiropentane (**11**, 160 mg, 2.00 mmol) and dimethyl fumarate (**19**, 288 mg, 2.00 mmol) were added. The bottle was tightly closed, and the mixture was stirred at 80 °C for 48 h. After cooling to room temperature, the reaction mixture was taken up in diethyl ether (50 mL). The solution was washed with water (5 × 25 mL) and dried ($MgSO_4$). After removal of the solvent in a rotary evaporator, the residue was subjected to chromatography on silica gel (2 × 20 cm, hexane/diethyl ether, 3:1). The obtained 71 mg of a milky colorless oil did not give interpretable ^{1}H and ^{13}C NMR spectra.

Sequential Reaction Involving Methylenespiropentane (11) Iodobenzene (12), Morpholine (25) and Dimethyl Fumarate (19): Palladium acetate (22.4 mg, 100 μmol, 5 mol-%) and tris(2-furyl)phosphane (46.4 mg, 200 μmol, 10 mol-%), were suspended in anhydrous DMF (1 mL) in a screw-cap Pyrex bottle. Argon was bubbled through the mixture for 5 min, then morpholine (**25**, 174 mg, 2.00 mmol), triethylamine (202 mg, 2.00 mmol), iodobenzene (**12**, 408 mg, 2.00 mmol) and methylenespiropentane (**11**) (320 mg, 4.00 mmol) were added. After having stirred the mixture at 80 °C for 3 h, the bottle was cooled to ambient temperature, dimethyl fumarate (**19**, 576 mg, 4.00 mmol) was added, and the mixture was stirred at 80 °C for 48 h in a preheated oil bath. After cooling to room temperature, the reaction mixture was taken up in diethyl ether (20 mL). The solution was washed with water (2 × 20 mL). The aqueous phase was extracted with diethyl ether (2 × 20 mL). The combined organic phases were dried ($MgSO_4$). After removal of the solvent in a rotary evaporator, the residue was subjected to column chromatography on silica gel (100 g, 3 × 30 cm, light petroleum/ethyl acetate, 1:1) to yield **26** (25 mg, 5%, colorless oil), **27** (240 mg, 31%, colorless oil) and **28** (39 mg, 8%, colorless oil).

4-(2-Methylene-4-phenylpent-4-enyl)morpholine (26): R_f = 0.60 (light petroleum/ethyl acetate, 3:1). IR (film): $\tilde{\nu}$ = 3081, 3023, 2958, 2912, 2853, 2805, 1739, 1701, 1650, 1626, 1574, 1495, 1453, 1346, 1329, 1290, 1268, 1243, 1118, 1071, 1035, 1012, 965, 867, 779, 733, 705 cm^{-1}. ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.35 (t, J = 4.3 Hz, 4 H, CH_2NCH_2), 2.86 (s, 2 H), 3.30 (s, 2 H), 3.70 (t, J = 4.7 Hz, 4 H, CH_2OCH_2), 4.94 (d, J = 15 Hz, 2 H, vinyl-H), 5.14 (s, 1 H, vinyl-H), 5.45 (d, J = 1.6 Hz, 1 H, vinyl-H), 7.24–7.34 (m, 3 H, Ph), 7.44–7.48 (m, 2 H, Ph) ppm. ^{13}C NMR (50.3 MHz, $CDCl_3$, DEPT): δ = 40.01 (–, CH_2), 53.56 (–, CH_2NCH_2), 63.94 (–, CH_2), 67.13 (–, CH_2OCH_2), 114.55 (–, vinyl-C), 114.81 (–, vinyl-C), 126.12 (+, 2 × Ph), 127.31 (+, Ph), 128.08 (+, 2 × Ph), 140.98 (C_{quat}), 143.70 (C_{quat}), 145.65 (C_{quat}) ppm. MS (70 eV, EI): *m*/*z* (%) = 243 (74) [M^+], 228 (15), 213 (10), 198 (13), 184 (8), 143 (23), 138 (46), 115 (20), 100 (100), 95 (18), 77 (12), 56 (14).

Dimethyl 4-[1-(Morpholin-4-yl)ethyl]-5-phenylcyclohex-4-ene-1,2-dicarboxylate (27): R_f = 0.61 (light petroleum/ethyl acetate, 1:1). IR (film): $\tilde{\nu}$ = 3054, 3020, 2952, 2849, 2805, 2688, 1734, 1600, 1492, 1437, 1379, 1346, 1331, 1297, 1259, 1221, 1162, 1117, 1070, 1004, 911, 864, 798, 771, 744, 704 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.97 (d, J = 6.8 Hz, 3 H, CH_3), 2.10–2.30 (m, 4 H, CH_2NCH_2), 2.34–2.40 (m, 1 H, 3-H or 6-H), 2.49–2.58 (m, 1 H, 3-H or 6-H), 2.67–2.91 (AB system: δ_A = 2.89, δ_B = 2.70, J_{AB} = 13.0 Hz, 2 H, 3-H or 6-H), 2.96–3.12 (m, 3 H, 3 × C*H*), 3.56–3.61 (m, 4 H, CH_2OCH_2), 3.63 (s, 3 H, OCH_3), 3.69 (s, 3 H, OCH_3), 6.95–6.99 (m, 2 H, Ph), 7.17–7.29 (m, 3 H, Ph) ppm. ^{13}C NMR (75.5 MHz, $CDCl_3$, DEPT): δ = 15.66 (+, CH_3), 31.01 (+, *C*H), 35.80 (–, C-3 or C-6), 36.75 (+, *C*H), 46.08 (+, *C*H), 51.65 (+, OCH_3), 51.79 (+, OCH_3), 53.22 (–, CH_2NCH_2), 57.89 (–, C-3 or C-6), 60.82 (–, CH_2OCH_2), 126.61 (+, Ph), 128.00 (+, 2 × Ph), 128.13 (+, 2 × Ph), 133.69 (C_{quat}), 133.41 (C_{quat}), 141.70 (C_{quat}), 174.06 (C_{quat}, C=O), 175.86 (C_{quat}, C=O) ppm. MS (70 eV, EI): *m*/*z* (%) = 387 (100) [M^+], 356 (8), 328 (10), 268 (8), 241 (14), 181 (40), 100 (12). $C_{22}H_{29}NO_5$ (387.5): calcd. C 68.20, H 7.54; found C 67.97, H 7.69.

4-[2-(1-Phenylvinyl)but-2-enyl]morpholine (28): R_f = 0.71 (light petroleum/ethyl acetate, 1:1). IR (film): $\tilde{\nu}$ = 3056, 3023, 2954, 2850,

2804, 2759, 1737, 1496, 1458, 1437, 1411, 1381, 1349, 1329, 1298, 1206, 1223, 1197, 1162, 1117, 1066, 1004, 982, 915, 864, 801, 771, 742, 706 cm^{-1}. ^1H NMR (250 MHz, $CDCl_3$): δ = 1.68 (d, J = 6.8 Hz, 3 H, CH_3), 2.38 (t, J = 4.6 Hz, 4 H, CH_2NCH_2), 2.91 (s, 2 H), 3.65 (t, J = 4.7 Hz, 4 H, CH_2OCH_2), 5.05 (d, J = 1.6 Hz, 1 H, vinyl-H), 5.58 (d, J = 1.6 Hz, 1 H, vinyl-H), 5.78 (q, J = 6.8 Hz, 1 H, vinyl-H), 7.17–7.39 (m, 5 H, Ph) ppm. ^{13}C NMR (50.3 MHz, $CDCl_3$, DEPT): δ = 14.56 (+, CH_3), 53.39 (–, CH_2NCH_2), 64.47 (–, CH_2), 66.99 (–, CH_2OCH_2), 114.78 (–, vinyl-C), 125.83 (+, vinyl-C), 126.41 (+, 2 × Ph), 127.36 (+, Ph), 128.20 (+, 2 × Ph), 137.59 (C_{quat}), 139.79 (C_{quat}), 146.76 (C_{quat}) ppm. MS (70 eV, EI): m/z (%) = 243 (48) [M^+], 228 (8), 198 (8), 143 (8), 128 (9), 115 (8), 100 (100), 56 (10).

General Procedure for the One-Pot, Two-Step Queuing Cascade Involving Methylenespiropentane (11), Functionalized Iodoarenes 33a–g, 42 and Dimethyl Fumarate (19) (GP): Palladium acetate (22.4 mg, 100 μmol, 5 mol-%) and tris(2-furyl)phosphane (46.4 mg, 200 μmol, 10 mol-%), were suspended in anhydrous DMF (1 mL) in a screw-cap Pyrex bottle. Argon was bubbled through the mixture for 5 min, then triethylamine (202 mg, 2.00 mmol), the respective iodoarene (**33a**–**g** or **42**, 2.00 mmol) and methylenespiropentane (**11**) (320 mg, 4.00 mmol) were added. After having stirred the mixture at the stated temperature for the given time, the bottle was cooled to ambient temperature, dimethyl fumarate (**19**, 576 mg, 4.00 mmol) was added, and then the mixture was stirred at the given temperature in a preheated oil bath for an additional time as stated. After cooling to room temperature, the reaction mixture was taken up in diethyl ether (20 mL). The solution was washed with water (2 × 20 mL). The aqueous phase was extracted with diethyl ether (2 × 20 mL). The combined organic phases were dried ($MgSO_4$). After removal of the solvent in a rotary evaporator, the residue was subjected to chromatography on silica gel.

Dimethyl 5-Methyl-1,2,3,4,5,7-hexahydrodibenzo[*c*,*e*]oxepine-2,3-dicarboxylate (36a): According to the GP, $Pd(OAc)_2$ (22.4 mg, 100 μmol), tris(2-furyl)phosphane (46.4 mg, 200 μmol), Et_3N (202 mg, 2.00 mmol), 2-iodobenzyl alcohol (**33a**, 468 mg, 2.00 mmol) and methylenespiropentane (**11**, 320 mg, 4.00 mmol) were stirred in anhydrous DMF (1 mL) at 80 °C for 3 h. After cooling the mixture to room temperature, dimethyl fumarate (**19**, 576 mg, 4.00 mmol) was added, and the mixture stirred at 80 °C for 48 h. After workup and column chromatography on silica gel (100 g, 3 × 30 cm, light petroleum/ethyl acetate, 3:1), **36a** (145 mg, 22%, colorless solid) was obtained as a mixture of two diastereomers (ratio 1:1 according to NMR). R_f = 0.32 (light petroleum/ethyl acetate, 3:1). IR (film): $\tilde{\nu}$ = 2953, 2857, 1735, 1487, 1437, 1381, 1333, 1246, 1198, 1176, 1083, 1036, 914, 843, 755 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 1.16 (d, J = 6.9 Hz, 3 H, CH_3), 1.17 (d, J = 6.1 Hz, 3 H, CH_3), 2.19–2.49 (m, 2 H, 1-H or 4-H), 2.54–2.65 (m, 3 H, 1-H or 4-H), 2.79–3.13 [m, 7 H, 2 × (2-H + 3-H), 1-H or 4-H], 3.68 (s, 9 H, 3 × OCH_3), 3.71 (s, 3 H, OCH_3), 3.76–3.89 (m, 2 H, 2 × 5-H), 4.17 (d, J = 12.5 Hz, 1 H, 7-H), 4.21 (d, J = 12.5 Hz, 1 H, 7-H), 4.37 (d, J = 3.1 Hz, 1 H, 7-H), 4.41 (d, J = 3.1 Hz, 1 H, 7-H), 7.19–7.37 (m, 8 H, Ar) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, DEPT): δ = 16.22 (+, CH_3), 16.63 (+, CH_3), 26.99 (–, C-1 or C-4), 28.07 (–, C-1 or C-4), 30.39 (–, C-1 or C-4), 31.20 (–, C-1 or C-4), 40.92 (+, C-2 or C-3), 40.93 (+, C-2 or C-3), 41.55 (+, C-2 or C-3), 41.78 (+, C-2 or C-3), 52.00 (+, 2 × OCH_3), 52.04 (+, 2 × OCH_3), 67.72 (–, C-7), 67.77 (–, C-7), 69.51 (+, C-5), 70.17 (+, C-5), 125.19 (+, Ar), 125.55 (+, Ar), 127.59 (+, Ar), 127.89 (+, Ar), 128.23 (+, Ar), 128.25 (+, Ar), 128.88 (+, Ar), 129.27 (+, Ar), 132.38 (C_{quat}), 132.84 (C_{quat}), 133.60 (C_{quat}), 134.26 (C_{quat}), 136.04 (C_{quat}), 136.45 (C_{quat}), 140.80 (C_{quat}), 141.94 (C_{quat}), 174.49 (C_{quat}, C=O), 174.53 (C_{quat}, C=O), 174.77 (C_{quat}, C=O), 175.11 (C_{quat}, C=O) ppm. MS (70 eV, EI): m/z (%) = 330 (30) [M^+], 315 (11) [$M^+ - CH_3$], 299 (17), 270 (22), 252 (70), 227 (38), 211 (18), 195 (22), 193 (66), 167 (100), 165 (34), 105 (34), 84 (85), 79 (38), 53 (24), 43 (38). $C_{19}H_{22}O_5$ (330.4): calcd. C 69.07, H 6.71; found C 68.77, H 6.56. ^1H and ^{13}C NMR chemical shifts are given in a single series for both diastereomers, because the peaks in the ^1H and ^{13}C NMR spectra could not be fully assigned to individual diastereomers. IR, EI-MS measurements and elemental analysis were carried out with the mixture of diastereomers.

Dimethyl 6-Benzyl-5-methyl-2,3,4,5,6,7-hexahydro-1*H*-dibenzo[*c*,*e*]azepine-2,3-dicarboxylate (36b) and Dimethyl 6-Benzyl-4-methyl-2,3,4,5,6,7-hexahydro-1*H*-dibenzo[*c*,*e*]azepine-2,3-dicarboxylate (37b): According to the GP, $Pd(OAc)_2$ (22.4 mg, 100 μmol), tris(2-furyl)phosphane (46.4 mg, 200 μmol), Et_3N (202 mg, 2.00 mmol), (benzyl)(2-iodobenzyl)amine (**33b**, 646 mg, 2.00 mmol) and methylenespiropentane (**11**, 320 mg, 4.00 mmol) were stirred in anhydrous DMF (1 mL) at 80 °C for 3 h. After cooling the mixture to room temperature, dimethyl fumarate (**19**, 576 mg, 4.00 mmol) was added, and the mixture was stirred at 80 °C for 48 h. Workup and column chromatography on silica gel (100 g, 3 × 30 cm, light petroleum/ethyl acetate, 1:1) yielded **36b** (186 mg, 22%, colorless oil) as a mixture of two diastereomers (ratio 1.6:1 according to NMR) and **37b** (43 mg, 5% colorless oil).

Major Diastereomer 36b: R_f = 0.54 (light petroleum/ethyl acetate, 1:1). IR (film): $\tilde{\nu}$ = 3064, 3037, 2991, 2895, 2798, 1734, 1726, 1455, 1437, 1373, 1325, 1300, 1242, 1202, 1175, 1154, 1130, 1088, 1067, 1029, 1007, 911, 877, 836, 807, 755, 734, 701 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 1.13 (d, J = 6.8 Hz, 3 H, CH_3), 2.33–2.45 (m, 2 H, 1-H or 4-H), 2.73–2.80 (m, 1 H, 1-H or 4-H), 2.88–3.02 [m, 4 H, 1-H or 4-H, 2-H, 3-H, 5-H], 3.24–3.38 (AB system: δ_A = 3.35, δ_B = 3.27, J_{AB} = 12.2 Hz, 2 H, Bn), 3.58 (s, 2 H, 7-H), 3.71 (s, 3 H, OCH_3), 3.75 (s, 3 H, OCH_3), 7.14–7.41 (m, 9 H, Ar, Ph) ppm. ^{13}C NMR (50.3 MHz, $CDCl_3$, DEPT): δ = 16.26 (+, CH_3), 30.79 (–, C-1 or C-4), 31.63 (–, C-1 or C-4), 41.81 (+, C-2 or C-3), 41.89 (+, C-2 or C-3), 52.03 (+, OCH_3), 52.06 (+, OCH_3), 54.81 (–, Bn), 55.63 (–, C-7), 56.72 (+, C-5), 125.50 (+, Ar), 126.88 (+, Ar), 127.10 (+, Ar), 127.37 (+, Ar), 128.36 (+, 2 × Ph), 128.98 (+, 2 × Ph), 129.73 (+, Ph), 133.26 (C_{quat}), 133.54 (C_{quat}), 135.54 (C_{quat}), 140.01 (C_{quat}), 141.04 (C_{quat}), 175.04 (C_{quat}, C=O), 175.40 (C_{quat}, C=O) ppm. MS (70 eV, EI): m/z (%) = 419 (8) [M^+], 404 (100) [$M^+ - CH_3$], 388 (5), 91 (40). $C_{26}H_{29}NO_4$ (419.5): calcd. C 74.44, H 6.97; found C 74.21, H 6.72.

Minor Diastereomer 36b: R_f = 0.49 (light petroleum/ethyl acetate, 1:1). ^1H NMR (300 MHz, $CDCl_3$): δ = 1.00 (d, J = 6.7 Hz, 3 H, CH_3), 2.45–2.75 (m, 2 H, 1-H + 4-H), 3.05–3.16 (m, 3 H, 2-H, 3-H, 5-H), 3.20–3.37 (AB system: δ_A = 3.35, δ_B = 3.22, J_{AB} = 11.1 Hz, 2 H, Bn), 3.51–3.86 (AB system: δ_A = 3.83, δ_B = 3.54, J_{AB} = 13.1 Hz, 2 H, 7-H), 3.72 (s, 3 H, OCH_3), 3.74 (s, 3 H, OCH_3), 7.17–7.41 (m, 9 H, Ar, Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, DEPT): δ = 17.92 (+, CH_3), 30.57 (–, C-1 or C-4), 31.13 (–, C-1 or C-4), 41.28 (+, C-2 or C-3), 41.32 (+, C-2 or C-3), 52.07 (+, 2 × OCH_3), 55.95 (–, Bn), 57.10 (+, C-5), 57.45 (–, C-7), 125.05 (+, Ar), 126.89 (+, Ar), 127.03 (+, Ar), 127.39 (+, Ar), 128.30 (+, 2 × Ph), 128.87 (+, 2 × Ph), 129.42 (+, Ph), 131.45 (C_{quat}), 132.95 (C_{quat}), 136.00 (C_{quat}), 139.83 (C_{quat}), 142.01 (C_{quat}), 174.79 (C_{quat}, C=O), 174.86 (C_{quat}, C=O) ppm.

IR, ^1H and ^{13}C NMR and EI-MS measurements and elemental analysis were carried out with the mixture of diastereomers.

37b: IR (film): $\tilde{\nu}$ = 3061, 3025, 2950, 2799, 1734, 1495, 1436, 1362, 1265, 1198, 1174, 1121, 1063, 1027, 912, 848, 755, 736, 700, 668 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 1.30 (d, J = 7.1 Hz, 3 H, CH_3), 2.33 (d, J = 11.0 Hz, 1 H, 5-H), 2.40–2.50 (m, 1 H, 1-H),

2.59–2.67 (m, 2 H, 2-H or 3-H and 4-H), 2.80 (d, J = 11.1 Hz, 1 H, 5-H), 2.93 (dd, J = 4.8, 17.0 Hz, 1 H, 1-H), 3.03–3.12 (m, 1 H, 2-H or 3-H), 3.35–3.49 (m, 2 H, Bn or 7-H), 3.69 (s, 3 H, OCH_3), 3.73 (s, 3 H, OCH_3), 3.63–3.77 (m, 2 H, Bn or 7-H), 7.19–7.36 (m, 9 H, Ar, Ph) ppm. ^{13}C NMR (50.3 MHz, $CDCl_3$, DEPT): δ = 19.22 (+, CH_3), 30.80 (–, C-1), 38.21 (+, C-2 or C-3), 42.54 (+, C-2 or C-3), 50.40 (+, C-4), 51.90 (+, OCH_3), 51.97 (+, OCH_3), 52.90 (–, C-5), 55.50 (–, Bn or C-7), 59.71 (–, Bn or C-7), 125.70 (+, Ar), 126.94 (+, 2 × Ar), 127.30 (+, Ar), 128.24 (+, 2 × Ph), 128.81 (+, 2 × Ph), 129.92 (+, Ph), 132.99 (C_{quat}), 134.94 (C_{quat}), 135.94 (C_{quat}), 139.31 (C_{quat}), 141.00 (C_{quat}), 174.53 (C_{quat}, C=O), 175.34 (C_{quat}, C=O) ppm. MS (70 eV, EI): m/z (%) = 419 (42) [M^+], 388 (8), 327 (16), 318 (12), 268 (14), 220 (20), 192 (23), 182 (34), 165 (32), 150 (22), 105 (83), 91 (100), 84 (78), 59 (54), 45 (35). HRMS-ESI for $C_{26}H_{29}NO_4$ (419.53): calcd. for $[M + H]^+$ 420.21693, found 420.21705.

Dimethyl 9,10-Dimethoxy-5-methyl-1,2,3,4,5,7-hexahydrodibenzo-[*c*,*e*]oxepine-2,3-dicarboxylate (36c): According to the GP, $Pd(OAc)_2$ (22.4 mg, 100 μmol), tris(2-furyl)phosphane (46.4 mg, 200 μmol), Et_3N (202 mg, 2.00 mmol), 2-iodo-4,5-dimethoxybenzyl alcohol (**33c**, 588 mg, 2.00 mmol) and methylenespiropentane (**11**, 320 mg, 4.00 mmol) were stirred in anhydrous DMF (1 mL) at 80 °C for 3 h. After cooling the mixture to room temperature, dimethyl fumarate (**19**, 576 mg, 4.00 mmol) was added, and the mixture stirred at 80 °C for 48 h. After workup and column chromatography on silica gel (100 g, 3 × 30 cm, light petroleum/ethyl acetate, 3:1), **36c** (142 mg, 18%, colorless solid) was obtained as a mixture of two diastereomers (ratio 1.6:1 according to NMR). R_f = 0.51 (light petroleum/ethyl acetate, 3:1). IR (KBr): $\tilde{\nu}$ = 2952, 2854, 1736, 1605, 1573, 1515, 1437, 1375, 1248, 1199, 1174, 1131, 1081, 1023, 863, 803, 768 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 1.15 (d, J = 6.9 Hz, 3 H, CH_3), 1.16 (d, J = 6.6 Hz, 3 H, CH_3), 2.15–2.41 (m, 2 H, 1-H or 4-H), 2.52–2.61 (m, 3 H, 1-H or 4-H), 2.71–3.08 [m, 7 H, 2 × (2-H + 3-H), 1-H or 4-H], 3.67 (s, 3 H, OCH_3), 3.68 (s, 6 H, 2 × OCH_3), 3.69 (s, 3 H, OCH_3), 3.73–3.82 (m, 2 H, 2 × 5-H), 3.84 (s, 6 H, 2 × OCH_3), 3.85 (s, 3 H, OCH_3), 3.86 (s, 3 H, OCH_3), 4.09–4.22 (m, 4 H, 2 × 7-H), 6.73 (s, 1 H, Ar), 6.78 (s, 2 H, Ar), 6.80 (s, 1 H, Ar) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, DEPT): δ = 16.52 (+, CH_3), 17.46 (+, CH_3), 26.91 (–, C-1 or C-4), 28.01 (–, C-1 or C-4), 30.45 (–, C-1 or C-4), 31.31 (–, C-1 or C-4), 40.91 (+, C-2 or C-3), 40.96 (+, C-2 or C-3), 41.55 (+, C-2 or C-3), 41.82 (+, C-2 or C-3), 52.00 (+, 4 × OCH_3), 55.78 (+, 2 × OCH_3), 55.84 (+, 2 × OCH_3), 67.31 (–, C-7), 67.40 (–, C-7), 69.39 (+, C-5), 69.95 (+, C-5), 108.07 (+, Ar), 108.48 (+, Ar), 111.65 (+, Ar), 111.99 (+, Ar), 128.84 (C_{quat}), 129.32 (C_{quat}), 131.56 (C_{quat}), 132.08 (C_{quat}), 133.19 (C_{quat}), 133.61 (C_{quat}), 134.21 (C_{quat}), 134.49 (C_{quat}), 148.07 (C_{quat}), 148.30 (C_{quat}), 148.72 (2 × C_{quat}), 174.47 (C_{quat}, C=O), 174.59 (C_{quat}, C=O), 174.77 (C_{quat}, C=O), 175.11 (C_{quat}, C=O) ppm. MS (70 eV, EI): m/z (%) = 390 (100) [M^+], 375 (47) [$M^+ - CH_3$], 359 (22), 312 (16), 287 (55), 253 (9), 227 (12), 59 (10). $C_{21}H_{26}O_7$ (390.4): calcd. C 64.60, H 6.71; found C 64.35, H 6.41. ^1H and ^{13}C NMR chemical shifts are given in a single series for both diastereomers, because the peaks in the ^1H and ^{13}C NMR spectra could not be fully assigned to the individual diastereomers. IR, EI-MS measurements and elemental analysis were carried out with the mixture of diastereomers.

Dimethyl 5-Methyl-2,3,5,7-tetrahydro-1*H*,4*H*-6,9,11-trioxabenzo-[3,4]cyclohepta[1,2-*f*]indene-2,3-dicarboxylate (36d): According to the GP, $Pd(OAc)_2$ (22.4 mg, 100 μmol), tris(2-furyl)phosphane (46.4 mg, 200 μmol), Et_3N (202 mg, 2.00 mmol), (6-iodobenzo[1,3]-dioxol-5-yl)methanol (**33d**, 556 mg, 2.00 mmol) and methylenespiropentane (**11**, 320 mg, 4.00 mmol) were stirred in anhydrous DMF (1 mL) at 80 °C for 3 h. After cooling the mixture to room temperature, dimethyl fumarate (**19**, 576 mg, 4.00 mmol) was added, and the mixture stirred at 80 °C for 48 h. After workup and column chromatography on silica gel (100 g, 3 × 30 cm, light petroleum/ethyl acetate, 3:1), **36d** (155 mg, 21%, colorless solid) was obtained as a mixture of two diastereomers (ratio 1.6:1 according to NMR). R_f = 0.24 (light petroleum/ethyl acetate, 3:1). IR (KBr): $\tilde{\nu}$ = 2977, 2953, 2907, 2857, 1724, 1504, 1484, 1436, 1381, 1324, 1267, 1242, 1195, 1155, 1077, 1039, 1014, 976, 934, 871, 820, 793, 739 cm^{-1}. ^1H NMR (250 MHz, $CDCl_3$): δ = 1.17 (d, J = 6.6 Hz, 3 H, CH_3), 1.18 (d, J = 7.0 Hz, 3 H, CH_3), 2.17–2.41 (m, 2 H, 1-H or 4-H), 2.52–2.64 (m, 3 H, 1-H or 4-H), 2.74–2.89 (m, 2 H, 1-H or 4-H), 2.91–3.05 [m, 3 H, 2 × (2-H or 3-H), 1-H or 4-H], 2.08–3.13 [m, 2 H, 2 × (2-H or 3-H)], 3.72 (s, 9 H, 3 × OCH_3), 3.74 (s, 3 H, OCH_3), 3.77–3.90 (m, 2 H, 2 × 5-H), 4.10 (t, J = 10.5 Hz, 2 H, 7-H), 4.27 (d, J = 3.0 Hz, 1 H, 7-H), 4.32 (d, J = 3.3 Hz, 1 H, 7-H), 5.96 (s, 2 H, 10-H), 5.97 (s, 2 H, 10-H), 6.76 (s, 1 H, Ar), 6.78 (s, 1 H, Ar), 6.80 (s, 1 H, Ar), 6.81 (s, 1 H, Ar) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, DEPT): δ = 16.47 (+, CH_3), 17.34 (+, CH_3), 26.73 (–, C-1 or C-4), 27.96 (–, C-1 or C-4), 30.33 (–, C-1 or C-4), 31.30 (–, C-1 or C-4), 40.84 [+, 2 × C-2 or C-3], 41.51 (+, C-2 or C-3), 41.74 (+, C-2 or C-3), 52.04 (+, 4 × OCH_3), 67.24 (–, C-7), 67.36 (–, C-7), 69.28 (+, C-5), 69.74 (+, C-5), 101.16 (–, C-10), 101.23 (–, C-10), 105.48 (+, Ar), 105.87 (+, Ar), 109.09 (+, Ar), 109.45 (+, Ar), 130.03 (C_{quat}), 130.57 (C_{quat}), 131.67 (C_{quat}), 132.23 (C_{quat}), 133.60 (C_{quat}), 134.17 (C_{quat}), 134.77 (C_{quat}), 136.02 (C_{quat}), 146.71 (C_{quat}), 146.97 (C_{quat}), 147.64 (C_{quat}), 147.73 (C_{quat}), 174.42 (C_{quat}, C=O), 174.50 (C_{quat}, C=O), 174.75 (C_{quat}, C=O), 175.10 (C_{quat}, C=O) ppm. MS (70 eV, EI): m/z (%) = 374 (64) [M^+], 359 (34) [$M^+ - CH_3$], 343 (16), 314 (21), 296 (34), 271 (100), 239 (20), 237 (28), 211 (35), 181 (64), 153 (27), 128 (12), 115 (11), 57 (26), 43 (73). $C_{20}H_{22}O_7$ (374.4): calcd. C 64.16, H 5.92; found C 64.39, H 5.80. ^1H and ^{13}C NMR chemical shifts are given in a single series for both diastereomers, because the peaks in the ^1H and ^{13}C NMR spectra could not be fully assigned to the individual diastereomers. IR, EI-MS measurements and elemental analysis were carried out with the mixture of diastereomers.

(Benzyl)(6-iodobenzo[1,3]dioxol-5-ylmethyl)amine (33e): A solution of 5-(chloromethyl)-6-iodobenzo[1,3]dioxole (0.785 g, 2.65 mmol), benzylamine (1.16 mL, 10.6 mmol) and K_2CO_3 (1.82 g, 13.2 mmol) in DME (15 mL) was heated under reflux. The progress of the reaction was monitored by TLC, and the heating was terminated, when the starting dioxole had disappeared (ca. 4 h). The reaction mixture was filtered at ambient temperature and concentrated in a rotary evaporator. The residue was subjected to column chromatography on silica gel (100 g, 3 × 30 cm, light petroleum/ethyl acetate, 3:1) to yield **33e** (812 mg, 84%, yellowish oil). IR (film): $\tilde{\nu}$ = 3315, 3084, 3061, 3025, 2893, 2829, 1500, 1476, 1453, 1406, 1385, 1363, 1230, 1113, 1039, 933, 864, 829, 738, 698 cm^{-1}. ^1H NMR (250 MHz, $CDCl_3$): δ = 1.78 (br. s, 1 H, NH), 3.75 (s, CH_2), 3.80 (s, CH_2), 5.96 (s, OCH_2O), 6.95 (s, 1 H, Ar), 7.24–7.36 (m, 6 H, Ar, Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, DEPT): δ = 52.93 (–, CH_2), 57.36 (–, CH_2), 87.09 (C_{quat}), 101.51 (–, OCH_2O), 109.86 (+, Ar), 118.52 (+, Ar), 126. 95 (+, Ph), 128. 14 (+, 2 × Ph), 128. 34 (+, 2 × Ph), 135.62 (C_{quat}), 139.99 (C_{quat}), 147.37 (C_{quat}), 148.33 (C_{quat}) ppm. MS (70 eV, EI): m/z (%) = 367 (26) [M^+], 276 (14), 261 (42), 240 (41), 135 (74), 106 (18), 91 (100), 76 (14). $C_{15}H_{14}INO_2$ (367.19): calcd. C 49.07, H 3.84; found C 48.95, H 3.83.

Dimethyl 6-Benzyl-5-methyl-2,3,4,5,6,7-hexahydro-1*H*-9,11-dioxa-6-azabenzo[3,4]cyclohepta[1,2-*f*]indene-2,3-dicarboxylate (36e): According to the GP, $Pd(OAc)_2$ (22.4 mg, 100 μmol), tris(2-furyl)-phosphane (46.4 mg, 200 μmol), Et_3N (202 mg, 2.00 mmol), (benzyl)(6-iodobenzo[1,3]dioxol-5-ylmethyl)amine (**33e**, 734 mg, 2.00 mmol) and methylenespiropentane (**11**, 320 mg, 4.00 mmol)

were stirred in anhydrous DMF (1 mL) at 80 °C for 3 h. After cooling the mixture to room temperature, dimethyl fumarate (**19**, 576 mg, 4.00 mmol) was added, and the mixture stirred at 80 °C for 48 h. After workup and column chromatography on silica gel (100 g, 3 × 30 cm, light petroleum/ethyl acetate, 1:1) **36e** (185 mg, 20%, colorless solid) was obtained as a mixture of two diastereomers (ratio 1.5:1 according to NMR). R_f = 0.52 (light petroleum/ethyl acetate, 1:1). IR (KBr): $\tilde{\nu}$ = 2948, 2891, 2789, 1732, 1502, 1483, 1457, 1437, 1369, 1325, 1261, 1239, 1177, 1129, 1035, 930, 884, 826, 749, 730, 703 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.01 (d, J = 6.8 Hz, 3 H, CH_3), 1.13 (d, J = 6.8 Hz, 3 H, CH_3), 2.27–2.73 [m, 8 H, 2 × (1-H + 4-H)], 2.79–3.00 (m, 3 H, 2-H, 3-H, 5-H), 3.06–3.23 [m, 7 H, (2-H + 3-H), (Bn or 7-H), 5-H], 2.48–3.62 (m, 3 H, Bn or 7-H), 3.70 (s, 3 H, OCH_3), 3.71 (s, 3 H, OCH_3), 3.72 (s, 3 H, OCH_3), 3.74 (s, 3 H, OCH_3), 3.70–3.74 (m, 1 H, Bn or 7-H)*, 5.91–5.94 (m, 4 H, 2 × 10-H), 6.64 (s, 1 H, Ar), 6.65 (s, 1 H, Ar), 6.73 (s, 1 H, Ar), 6.78 (s, 1 H, Ar), 7.24–7.29 (m, 10 H, Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, DEPT): δ = 16.12 (+, CH_3), 17.62 (+, CH_3), 30.50 (–, C-1 or C-4), 30.61 (–, C-1 or C-4), 30.79 (–, C-1 or C-4), 31.82 (–, C-1 or C-4), 41.18 (+, C-2 or C-3), 41.21 (+, C-2 or C-3), 41.80 (+, C-2 or C-3), 41.86 (+, C-2 or C-3), 52.03 (+, 4 × OCH_3), 54.31 (–, Bn or C-7), 55.38 (–, Bn or C-7), 55.46 (–, Bn or C-7), 56.88 (+, C-5), 57.23 (+, C-5), 57.23 (–, Bn or C-7), 100.94 (–, C-10), 100.99 (–, C-10), 105.55 (+, Ar), 105.97 (+, Ar), 109.66 (+, Ar), 109.90 (+, Ar), 126.85 (+, 2 × Ph), 128.27 (+, 2 × Ph), 128.33 (+, 2 × Ph), 128.79 (+, 2 × Ph), 128.87 (+, 2 × Ph), 129.39 (C_{quat}), 129.79 (C_{quat}), 131.23 (C_{quat}), 132.06 (C_{quat}), 132.58 (C_{quat}), 133.21 (C_{quat}), 134.65 (C_{quat}), 135.65 (C_{quat}), 139.83 (C_{quat}), 139.95 (C_{quat}), 146.24 (C_{quat}), 146.34 (C_{quat}), 146.95 (C_{quat}), 146.97 (C_{quat}), 174.68 (C_{quat}, C=O), 174.78 (C_{quat}, C=O), 174.95 (C_{quat}, C=O), 175.35 (C_{quat}, C=O) ppm. MS (70 eV, EI): m/z (%) = 448 (100) [M^+], 432 (4) [$M^+ - CH_3$], 91 (72). $C_{27}H_{29}NO_6$ (463.5): calcd. C 69.96, H 6.31; found C 70.22, H 6.11. ^{1}H and ^{13}C NMR chemical shifts are given in a single series for both diastereomers, because the peaks in the ^{1}H and ^{13}C NMR spectra could not be fully assigned to the individual diastereomers. * This multiplet overlaps with singlets of methoxy groups. IR, EI-MS measurements and elemental analysis were carried out with the mixture of diastereomers.

(7-Iodo-2,3-dihydrobenzo[1,4]dioxin-6-yl)methanol (33f): To a solution of (2,3-dihydrobenzo[1,4]dioxin-6-yl)methanol (2.15 g, 12.93 mmol) in anhydrous $CHCl_3$ (30 mL) at –5 °C were successively added silver trifluoroacetate (3.14 g, 14.2 mmol) and iodine (3.61 g, 14.2 mmol). After stirring for 5 min, the resulting heterogeneous mixture was filtered through a pad of Celite. The filtrate was washed with satd. aq. $Na_2S_2O_3$ (10 mL), dried with $MgSO_4$, filtered and concentrated in vacuo to give a pale yellow solid. Recrystallization from $CHCl_3$ afforded **33f** (3.5 g, 92%, colorless solid), m.p. 80–82 °C. IR (KBr): $\tilde{\nu}$ = 3283, 2977, 2922, 1734, 1576, 1483, 1456, 1401, 1299, 1273, 1260, 1180, 1147, 1070, 1051, 1042, 986, 962, 917, 892, 874, 852, 705, 664 cm^{-1}. ^{1}H NMR (250 MHz, $CDCl_3$): δ = 1.90 (br. s, 1 H, OH), 4.24 [s, $O(CH_2)_2O$], 4.56 (s, 2 H, Bn), 6.97 (s, 1 H, Ar), 7.31 (s, 1 H, Ar) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, DEPT): δ = 64.13 [–, $O(CH_2)_2O$], 68.34 (–, Bn), 85.44 (C_{quat}), 117.17 (+, Ar), 127.00 (+, Ar), 135.56 (C_{quat}), 143.42 (C_{quat}), 143.71 (C_{quat}), 155.37 (C_{quat}) ppm. MS (70 eV, EI): m/z (%) = 392 (100) [M^+], 137 (40), 93 (9), 65 (14), 53 (18), 50 (15). $C_9H_9IO_3$ (292.1): calcd. C 37.01, H 3.11; found C 36.81, H 2.85.

Dimethyl 5-Methyl-2,3,5,7,10,11-hexahydro-1*H*,4*H*-6,9,12-trioxabenzo[3,4]cyclohepta[1,2-*b*]naphthalene-2,3-dicarboxylate (36f): According to the GP, $Pd(OAc)_2$ (22.4 mg, 100 μmol), tris(2-furyl)phosphane (46.4 mg, 200 μmol), Et_3N (202 mg, 2.00 mmol), (7-iodo-2,3-dihydrobenzo[1,4]dioxin-6-yl)methanol (**33f**, 584 mg, 2.00 mmol) and methylenespiropentane (**11**, 320 mg, 4.00 mmol) were stirred in anhydrous DMF (1 mL) at 80 °C for 3 h. After cooling the mixture to room temperature, dimethyl fumarate (**19**, 576 mg, 4.00 mmol) was added, and the mixture stirred at 80 °C for 48 h. After workup and column chromatography on silica gel (100 g, 3 × 30 cm, light petroleum/ethyl acetate, 3:1), **36f** (178 mg, 23%, colorless solid) was obtained as a mixture of two diastereomers (ratio 1.1:1 according to NMR). R_f = 0.55 (light petroleum/ethyl acetate, 3:1). IR (KBr): $\tilde{\nu}$ = 2952, 2849, 1728, 1573, 1500, 1437, 1370, 1309, 1248, 1197, 1177, 1156, 1067, 1041, 1002, 978, 948, 926, 901, 887, 847, 783, 749 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.20 (d, J = 6.6 Hz, 3 H, CH_3), 1.21 (d, J = 6.6 Hz, 3 H, CH_3), 2.18–2.42 (m, 2 H, 1-H or 4-H), 2.54–2.56 (m, 2 H, 1-H or 4-H), 2.63–2.65 (m, 1 H, 1-H or 4-H), 2.74–2.87 (m, 2 H, 1-H or 4-H), 2.91–3.05 [m, 3 H, 2 × (2-H or 3-H), 1-H or 4-H], 3.08–3.13 [m, 2 H, 2 × (2-H or 3-H)], 3.73 (s, 9 H, 3 × OCH_3), 3.75 (s, 3 H, OCH_3), 3.83–3.98 (m, 2 H, 2 × 5-H), 4.11–4.34 (m, 4 H, 2 × 7-H), 4.26 [s, 8 H, 2 × (10-H + 11-H)], 6.80 (s, 1 H, Ar), 6.82 (s, 1 H, Ar), 6.84 (s, 2 H, Ar) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, DEPT): δ = 16.59 (+, CH_3), 17.58 (+, CH_3), 26.93 (–, C-1 or C-4), 28.04 (–, C-1 or C-4), 30.38 (–, C-1 or C-4), 31.33 (–, C-1 or C-4), 40.82 [+, 2 × C-2 or C-3], 41.53 (+, C-2 or C-3), 41.76 (+, C-2 or C-3), 51.95 (+, OCH_3), 51.99 (+, 3 × OCH_3), 64.28 [–, 2 × (C-10 + C-11)], 67.07 (–, 2 × C-7), 69.45 (+, C-5), 70.31 (+, C-5), 114.09 (+, Ar), 114.46 (+, Ar), 117.45 (+, Ar), 117.77 (+, Ar), 129.86 (C_{quat}), 130.13 (C_{quat}), 131.51 (C_{quat}), 131.83 (C_{quat}), 133.04 (C_{quat}), 133.85 (C_{quat}), 134.08 (C_{quat}), 135.23 (C_{quat}), 142.61 (C_{quat}), 142.88 (C_{quat}), 143.29 (C_{quat}), 143.36 (C_{quat}), 174.46 (C_{quat}, C=O), 174.55 (C_{quat}, C=O), 174.80 (C_{quat}, C=O), 175.16 (C_{quat}, C=O) ppm. MS (70 eV, EI): m/z (%) = 388 (54) [M^+], 373 (22) [$M^+ - CH_3$], 357 (14), 328 (22), 310 (44), 285 (100), 251 (32), 225 (45), 59 (32), 49 (45), 43 (51). $C_{21}H_{24}O_7$ (388.4): calcd. C 64.94, H 6.23; found C 64.64, H 6.03. ^{1}H and ^{13}C NMR chemical shifts are given in a single series for both diastereomers, because the peaks in the ^{1}H and ^{13}C NMR spectra could not be fully assigned to the individual diastereomers. IR, EI-MS measurements and elemental analysis were carried out with the mixture of diastereomers.

Dimethyl 6-Methyl-4,6,7,8,9,10-hexahydro-1,3,5-trioxabenzo[3,4]cyclohepta[1,2-*e*]indene-8,9-dicarboxylate (36g): According to the GP, $Pd(OAc)_2$ (22.4 mg, 100 μmol), tris(2-furyl)phosphane (46.4 mg, 200 μmol), Et_3N (202 mg, 2.00 mmol), (5-iodobenzo[1,3]dioxol-4-yl)methanol (**33g**, 556 mg, 2.00 mmol) and methylenespiropentane (**11**, 320 mg, 4.00 mmol) were stirred in anhydrous DMF (1 mL) at 80 °C for 3 h. After cooling the mixture to room temperature, dimethyl fumarate (**19**, 576 mg, 4.00 mmol) was added, and the mixture stirred at 80 °C for 48 h. After workup and column chromatography on silica gel (100 g, 3 × 30 cm, light petroleum/ethyl acetate, 1:1), **36g** (219 mg, 29%, colorless solid) was obtained as a mixture of two diastereomers (ratio 1.1:1 according to NMR). R_f = 0.56 (light petroleum/ethyl acetate, 1:1). IR (KBr): $\tilde{\nu}$ = 2972, 2953, 2686, 1725, 1503, 1480, 1457, 1437, 1379, 1275, 1247, 1197, 1176, 1102, 1082, 1070, 1041, 1014, 977, 933, 887, 859, 797, 744 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.17 (d, J = 6.1 Hz, 3 H, CH_3), 1.18 (d, J = 6.9 Hz, 3 H, CH_3), 2.17–2.41 (m, 2 H, 9-H or 12-H), 2.46–2.58 (m, 3 H, 9-H or 12-H), 2.71–3.10 [m, 7 H, 2 × (10-H + 11-H), 9-H or 12-H], 3.69 (s, 9 H, 3 × OCH_3), 3.71 (s, 3 H, OCH_3), 3.86–3.97 (m, 2 H, 2 × 8-H), 3.97 (d, J = 11.3 Hz, 1 H, 6-H), 4.04 (d, J = 11.1 Hz, 1 H, 6-H), 4.68 (t, J = 11.0 Hz, 2 H, 6-H), 5.95 (d, J = 4.5 Hz, 4 H, 2 × 2-H), 6.75 (d, J = 1.9 Hz, 2 H, Ar), 6.78 (s, 2 H, Ar) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, DEPT): δ = 16.53 (+, CH_3), 17.43 (+, CH_3), 26.65 (–, C-9 or C-12), 28.03 (–, C-9 or C-12), 30.54 (–, C-9 or C-12), 31.61 (–, C-9 or C-12), 40.78 (+, C-10 or C-11), 40.84 (+, C-10 or C-11), 41.55 (+, C-10 or C-11), 41.86

(+, C-10 or C-11), 52.00 (+, 2 × OCH_3), 52.05 (+, 2 × OCH_3), 59.84 (–, 2 × C-6), 69.83 (+, C-8), 70.41 (+, C-8), 101.11 (–, C-2), 101.20 (–, C-2), 107.81 (+, Ar), 107.85 (+, Ar), 117.48 (C_{quat}), 117.73 (C_{quat}), 118.61 (+, Ar), 119.07 (+, Ar), 131.18 (C_{quat}), 131.61 (C_{quat}), 133.45 (C_{quat}), 134.04 (C_{quat}), 135.19 (C_{quat}), 136.51 (C_{quat}), 145.31 (C_{quat}), 145.64 (C_{quat}), 146.46 (C_{quat}), 146.75 (C_{quat}), 174.46 (C_{quat}, C=O), 174.51 (C_{quat}, C=O), 174.81 (C_{quat}, C=O), 175.17 (C_{quat}, C=O) ppm. MS (70 eV, EI): *m/z* (%) = 374 (74) [M^+], 359 (13) [$M^+ – CH_3$], 343 (17), 314 (26), 296 (83), 271 (100), 255 (30), 237 (40), 211 (46), 207 (24), 181 (66), 153 (28), 128 (15), 43 (22). $C_{20}H_{22}O_7$ (374.4): calcd. C 64.16, H 5.92; found C 64.12, H 5.74. ^1H and ^{13}C NMR chemical shifts are given in a single series for both diastereomers, because the peaks in the ^1H and ^{13}C NMR spectra could not be fully assigned to the individual diastereomers. IR, EI-MS measurements and elemental analysis were carried out with the mixture of diastereomers.

Dimethyl 5-Methyl-7-oxo-1,2,3,4,5,7-hexahydrodibenzo[*c*,*e*]oxepine-2,3-dicarboxylate (43): According to the GP, $Pd(OAc)_2$ (22.4 mg, 100 μmol), tris(2-furyl)phosphane (46.4 mg, 200 μmol), Et_3N (202 mg, 2.00 mmol), 2-iodobenzoic acid (**42**, 468 mg, 2.00 mmol) and methylenespiropentane (**11**, 320 mg, 4.00 mmol) were stirred in anhydrous DMF (1 mL) at 80 °C for 3 h. After cooling the mixture to room temperature, dimethyl fumarate (**19**, 576 mg, 4.00 mmol) was added, and the mixture stirred at 80 °C for 48 h. After workup and column chromatography on silica gel (100 g, 3 × 30 cm, light petroleum/ethyl acetate, 3:1), **43** (55 mg, 8%, yellowish oil) was obtained as a mixture of two diastereomers (ratio 1.8:1 according to NMR). R_f = 0.30 (light petroleum/ethyl acetate, 3:1). IR (film): $\tilde{\nu}$ = 3064, 2978, 2951, 2847, 1734, 1601, 1437, 1382, 1327, 1285, 1259, 1198, 1175, 1125, 1093, 1058, 1025, 1010, 936, 917, 769, 714 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 1.42 (d, J = 7.4 Hz, 3 H, CH_3), 1.45 (d, J = 7.1 Hz, 3 H, CH_3), 2.26–2.39 (m, 2 H, 1-H or 4-H), 2.56–2.63 (m, 3 H, 1-H or 4-H), 2.80–3.14 [m, 7 H, 2 × (2-H + 3-H), 1-H or 4-H], 3.67 (s, 3 H, OCH_3), 3.68 (s, 3 H, OCH_3), 3.70 (s, 3 H, OCH_3), 3.71 (s, 3 H, OCH_3), 4.71–4.79 (m, 2 H, 2 × 5-H), 7.30–7.41 (m, 4 H, Ar), 7.48–7.55 (m, 2 H, Ar), 7.82–7.86 (m, 2 H, Ar) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$, DEPT): δ = 15.82 (+, CH_3), 16.48 (+, CH_3), 26.79 (–, C-1 or C-4), 27.47 (–, C-1 or C-4), 30.25 (–, C-1 or C-4), 31.11 (–, C-1 or C-4), 40.75 (+, C-2 or C-3), 40.86 (+, C-2 or C-3), 41.05 (+, C-2 or C-3), 41.28 (+, C-2 or C-3), 52.15 (+, 4 × OCH_3), 72.80 (+, 2 × C-5), 125.37 (+, Ar), 125.97 (+, Ar), 128.08 (+, Ar), 128.30 (+, Ar), 130.73 (+, Ar), 130.85 (C_{quat}), 131.03 (+, Ar), 131.82 (C_{quat}), 132.02 (+, Ar), 133.81 (C_{quat}), 134.08 (C_{quat}), 134.37 (C_{quat}), 134.49 (C_{quat}), 136.76 (C_{quat}), 137.95 (C_{quat}), 169.95 (C_{quat}, C=O), 170.07 (C_{quat}, C=O), 173.92 (C_{quat}, C=O), 174.06 (C_{quat}, C=O), 174.45 (C_{quat}, C=O), 174.60 (C_{quat}, C=O) ppm. MS (70 eV, EI): *m/z* (%) = 344 (10) [M^+], 312 (29), 284 (30), 267 (37), 253 (86), 239 (28), 207 (41), 181 (100), 165 (49), 152 (26), 115 (13), 59 (16). HRMS-ESI for $C_{19}H_{20}O_6$ (344.37): calcd. for [M + H]$^+$ 345.13326, found 345.13314; calcd. for [M + NH_4]$^+$ 362.15981, found 362.15974. ^1H and ^{13}C NMR chemical shifts are given in a single series for both diastereomers, because the peaks in the ^1H and ^{13}C NMR spectra could not be fully assigned to the individual diastereomers. IR, EI-MS and ESI-HRMS measurements were carried out with the mixture of diastereomers.

Attempted Synthesis of Dimethyl 6-Methyl-5,6,7,8,9,10-hexahydrophenanthridine-8,9-dicarboxylate (39): According to the GP, $Pd(OAc)_2$ (22.4 mg, 100 μmol), tris(2-furyl)phosphane (46.4 mg, 200 μmol), Et_3N (202 mg, 2.00 mmol), 2-iodoaniline (**38**, 438 mg, 2.00 mmol) and methylenespiropentane (**11**, 320 mg, 4.00 mmol) were stirred in anhydrous DMF (1 mL) at 80 °C for 3 h. After cooling the mixture to room temperature, dimethyl fumarate (**19**, 576 mg, 4.00 mmol) was added, and the mixture stirred at 80 °C for 48 h. After workup and attempted column chromatography on silica gel (100 g, 3 × 30 cm, light petroleum/ethyl acetate, 3:1), none of the fractions contained any identifiable product.

Attempted Synthesis of Dimethyl 5-Methyl-1,3,4,5,7,8-hexahydro-2*H*-6-oxadibenzo[*a*,*c*]cyclooctene-2,3-dicarboxylate (41): According to the GP, $Pd(OAc)_2$ (22.4 mg, 100 μmol), tris(2-furyl)phosphane (46.4 mg, 200 μmol), Et_3N (202 mg, 2.00 mmol), 2-(2-iodophenyl) ethanol (**40**, 496 mg, 2.00 mmol) and methylenespiropentane (**11**, 320 mg, 4.00 mmol) were stirred in anhydrous DMF (1 mL) at 80 °C for 3 h. After cooling the mixture to room temperature, dimethyl fumarate (**19**, 576 mg, 4.00 mmol) was added, and the mixture stirred at 80 °C for 48 h. After workup and attempted column chromatography on silica gel (100 g, 3 × 30 cm, light petroleum/ethyl acetate, 3:1), none of the fractions contained any identifiable product.

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