Synthetic Studies on the 1,6-Methano[10]annulene Skeleton: A New Route That Provides Derivatives Substituted at the Bridge and on the Annulene Ring

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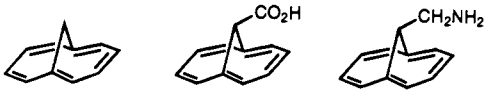
Abstract: A new synthetic route to the 1,6-methano[10]annulene skeleton has been developed. The key step in this route is the semi-benzylic Favorskii rearrangement of a [4.4.2]propellane to a [4.4.1]propellane. The methodology discussed here provides access to 1,6-methano[10]annulene derivatives bearing substituents on both the bridge carbon and the annulene ring. Control of the relative positioning of these appendages is achieved by introducing the annulene substituent via cuprate addition to an allylic lactone.

Introduction

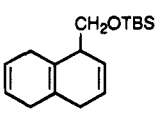
Since Vogel and Roth reported the preparation of the parent hydrocarbon (**1**) in 1964,[1] many aspects of the chemistry of 1,6-methano[10]annulene and its derivatives and higher homologues have been explored.[2] Recently, we have become interested in the behavior of amphiphilic versions of the 1,6-methano[10]annulene skeleton.[3] Derivatives bearing a polar group on the bridge carbon have an unusual amphiphilic topology, containing one polar face and one nonpolar face. We have designated such molecules "contrafacial amphiphiles", and preliminary studies have shown that their unique juxtaposition of polar and nonpolar surfaces leads to distinctive properties in aqueous solution.[4]

Simple amphiphilic derivatives of 1,6-methano[10]annulene, e.g., **2**[2a] and **3**,[5] have been known for many years; however, our interests required that we examine more highly functionalized derivatives, bearing substituents on the annulene ring as well as the bridge. At the outset of this work, we were surprised



1 **2** **3**

to discover that no bridged annulene derivatives of this type had been described in the literature. Our initial attempts to prepare molecules with the desired substitution pattern focused on the standard route to the 1,6-methano[10]annulene skeleton,[2] the key step of which involves dihalocarbene addition to isotetralin. Attempts to add dibromocarbene to isotetralin derivatives (e.g., **4**) were unsuccessful,[6] however, which forced



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us to consider alternative and more versatile routes to the bridged annulene core. Described below is the development of a new strategy for preparation of 1,6-methano[10]annulene-11-carboxylic acid (**2**)[2a,3] and derivatives substituted at a regiochemically defined position on the annulene ring. This strategy features a semi-benzylic Favorskii rearrangement[7] to generate a [4.4.1]propellane precursor to the bridged annulene. In addition to providing access to the desired substitution patterns, this new route provides a more efficient route to **2** than the dihalocarbene-based approach.

Results and Discussion

A New Route to 1,6-Methano[10]annulene-11-carboxylic Acid. Scheme 1 outlines our synthesis of 1,6-methano[10]-annulene-11-carboxylic acid (**2**). [4.4.2]Propellane **8** has previously been prepared in three steps and 45–55% yield from the anhydride of diacid **5**;[8] our three-step route from **5** to **8** proceeds in 92% overall yield.[9] Conversion of **8** to mesylate **9** was quantitative, and the semi-benzylic Favorskii rearrangement[7] provided [4.4.1]propellane **10** in 96% yield. Acid **10** has previously been prepared via the dihalocarbene route in 13% overall yield from isotetralin;[10] the overall yield of **10** from diacid **5** is 88%. Treatment of **10** with Br_2 rapidly produced a mixture of isomeric tribromo lactones, which, upon treatment with *t*-BuOK, provided annulene **2** in 95% yield. Methyl ester **11** was generated quantitatively by allowing **2** to react with $(CH_3O)_2SO_2$ and K_2CO_3. Acid **10** has previously been converted to ester **11** in 64% overall yield via esterification with CH_2N_2 followed by aromatization with DDQ.[10] Because only one chromatographic purification is required (of mesylate **9**), our synthesis of annulene **2** is particularly well-suited to multigram-scale preparations.

Regiochemically Controlled Access to Disbustituted [4.4.1]-Propellanes. Our new route to the bridged annulene core

(1) Vogel, E.; Roth, H. D. *Angew. Chem.* **1964**, *76*, 145.
(2) For leading references, see: (a) Vogel, E. *Spec. Publ.—Chem. Soc.* **1967**, No. 21, 113. (b) Vogel, E. *Isr. J. Chem.* **1980**, *20*, 215. (c) Simonetta, M. *Pure Appl. Chem.* **1980**, *52*, 1597.
(3) For a preliminary account of this work, see: Barrett, D. G.; Liang, G.-B.; Gellman, S. H. *J. Am. Chem. Soc.* **1992**, *114*, 6915.
(4) Barrett, D. G.; Gellman, S. H. *J. Am. Chem. Soc.* **1993**, *115*, 9343.
(5) Vogel, E.; Weyres, C.; Lepper, H.; Rautenstrauch, V. *Angew. Chem.* **1966**, *78*, 754.
(6) Liang, G.-B. Ph. D. Thesis, University of Wisconsin—Madison, 1992.
(7) Kirmse, W.; Olbricht, T. *Synthesis* **1975**, 173.
(8) Bloomfield, J. J.; Irelan, J. R. S. *J. Org. Chem.* **1966**, *31*, 2017.
(9) In situ trapping of acyloin condensation products with trimethylsilyl chloride: Bloomfield, J. J.; Melk, J. M. *Org. Synth.* **1977**, *57*, 1.
(10) Thompson, G. L.; Heyd, W. E.; Paquette, L. A. *J. Am. Chem. Soc.* **1974**, *96*, 3177.

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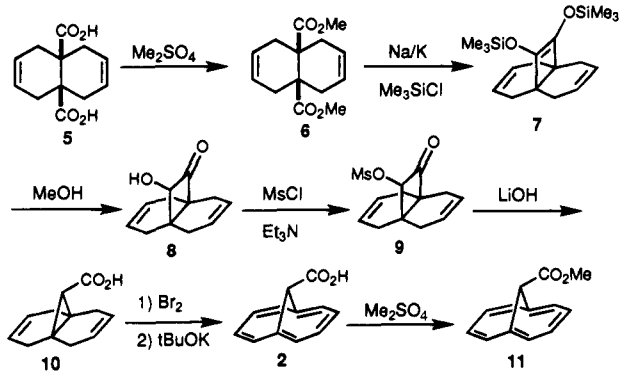
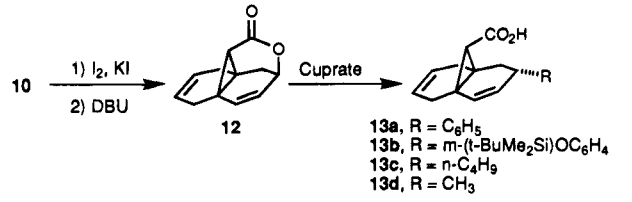
Scheme 1



Scheme 2



suggests a number of strategies for generating highly substituted derivatives.[11] One could, for example, use derivatives of butadiene to generate substituted analogues of diacid **5**. Alternatively, since the new route provides ready access to large quantities of ester **11**, one could attempt electrophilic aromatic substitution reactions on this substrate.[12] In each of these approaches, however, control over substituent juxtaposition (e.g., ring substituent relative to the bridge substituent) is likely to be problematic. We therefore focused on a strategy that would correlate the positions of substituents on the bridge and the annulene ring.

Acid **8** was treated with I_2/KI followed by DBU to generate allylic lactone **12** in good yield.[13] Figure 1 shows the crystal structure of **12**. This lactone reacted very efficiently with dialkyl or diaryl cuprate reagents to provide the disubstituted [4.4.1]-propellanes **13a–d**. In all cases, the major product was a single stereoisomer. Reaction of lower order cuprates with allylic carboxylates can lead to both α-substitution (S_N2-type) and γ-substitution (S_N2'-type) products.[14] The regiochemistry of the addition was unambiguously established for phenyl derivative **13a** via X-ray crystallography (Figure 2). Extensive ^1H NMR study (homonuclear decoupling) of the methyl ester of methyl derivative **13d** also indicated α-substitution, as did, by analogy, ^1H NMR data for **13b,c**.[11] The regioselectivity of these additions may be rationalized on the basis of detailed mechanistic studies by Goering et al.[14] These workers have proposed that cuprate additions to allylic carboxylates proceed via initial formation of a cuprate–olefin π-complex, which then undergoes oxidative addition in S_N2' fashion at the γ-carbon. The resulting σ-complex can undergo reductive elimination, to generate the γ-adduct, or the σ-complex can rearrange, via a π-allyl complex, to a second σ-complex, with Cu(III) bonded to the α-carbon. Reductive elimination of this second σ-complex generates the α-adduct. For lower order cuprates, Goering et al. found that

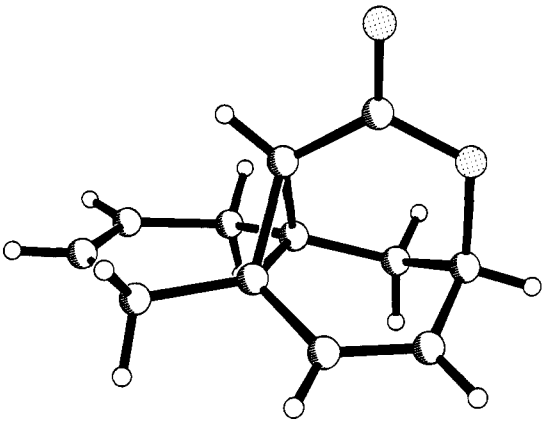


Figure 1. Ball-and-stick representation of the solid state structure of lactone **12**.

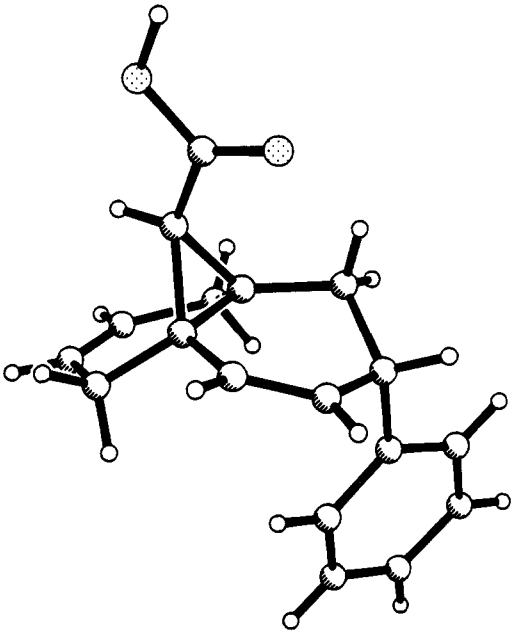
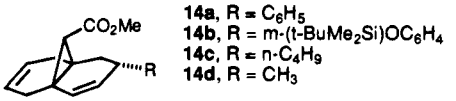


Figure 2. Ball-and-stick representation of the solid state structure of **13a**. The crystal contained two independent molecules, only one of which is shown.

the allylic rearrangement is faster than reductive elimination. With simple allylic carboxylate substrates, this situation often leads to formation of mixtures of α- and γ-addition products. The preference for α-addition in our systems may stem from a steric destabilization of the Cu(III) σ-complex at the γ-position and/or from stabilization of the σ-complex at the α-position by conjugation of the alkene with the cyclopropane moiety.[15]

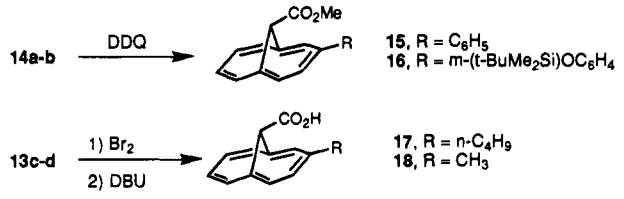
Aromatization of Disubstituted [4.4.1]Propellanes. In order to generate annulene ester **11** from [4.4.1]propellane acid **10**, Paquette et al.[10] first prepared the methyl ester and then aromatized with DDQ.[16] In order to follow this sequence of transformations, we prepared methyl esters **14a–c** using using



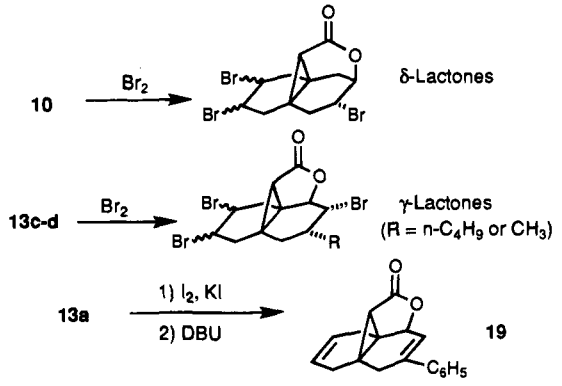
$(MeO)_2SO_2/K_2CO_3$; this protocol was problematic with **13d**, and ester **14d** was prepared instead through the action of

(11) Barret, D. G. Ph.D. Thesis, University of Wisconsin–Madison, 1993.
(12) We have recently reported a case in which attempted electrophilic acylation of **9** led instead to a Berson–Willcott rearrangement: Barrett, D. G.; Gellman, S. H. *Tetrahedron Lett.* **1994**, *35*, 2299.
(13) For a related iodolactonization, see ref 10.
(14) For leading references, see: (a) Goering, H. L.; Kantner, S. S. *J. Org. Chem.* **1983**, *48*, 721. (b) Goering, H. L.; Singleton, V. D. *J. Org. Chem.* **1983**, *48*, 1531. (c) Goering, H. L.; Kantner, S. S. *J. Org. Chem.* **1984**, *49*, 422.
(15) Goering et al. reported analogous observations with regard to the regiochemistry of cuprate additions.
(16) Nelson, P. H.; Untch, K. G. *Tetrahedron Lett.* **1969**, *10*, 4475.

Scheme 3



Scheme 4



BF_3 in MeOH at reflux.[17] Bridged annulenes **15** and **16**, bearing aromatic substituents, were readily generated via DDQ oxidation of the corresponding propellanes **13a,b** (these reactions also produced small amounts of the bridged annulenes that were epimeric at the bridge carbon). Treatment of propellanes **13c,d** with DDQ, however, led to decomposition. The milder oxidant *o*-chloranil also caused decomposition, and no reaction was observed with the even milder reagent *p*-chloranil. These difficulties with the alkyl-substituted cases led us to explore the bromination/dehydrobromination aromatization method originally used by Vogel et al.[1,2] to generate the parent hydrocarbon. Reaction of methyl derivative **13d** with Br_2 afforded quantitatively a mixture of tribromo lactones. Treatment of this mixture with *t*-BuOK produced some of annulene **18**, but this material was contaminated with byproducts that were not readily removed. Use of DBU as the base, in refluxing dioxane, led to a much cleaner reaction that provided **18** in 48% yield. The same reaction series with butyl derivative **13c** produced annulene **17** in 34% yield.

The moderate yields of alkyl-substituted annulene acids **17** and **18** obtained by the bromination/dehydrobromination route contrast with the excellent yield of annulene acid **2** provided by this approach. The origin of this variation in behavior is not clear but may stem from side reactions possible along the way to **17** and **18**, but not **2**. Reaction of [4.4.1]propellane **10** with Br_2 can produce only δ-lactones (Scheme 4); indeed, IR spectroscopy on this mixture of tribromo lactones showed carbonyl bands at 1721 and 1716 cm^{-1}, as expected for δ-lactones. Reaction of propellanes **13c,d**, however, could produce δ- and/or γ-lactones (Scheme 4); IR of the bromination products in these cases show bands in the range 1773−1745 cm^{-1}, suggesting that γ-lactones are predominant. This conclusion is strengthened by the fact that iodolactonization of propellane **13a** followed by elimination produces exclusively γ-lactone **19** (Scheme 4), the structure of which was verified crystallographically (Figure 3). The carbonyl stretch band of γ-lactone **19** occurs at 1742 cm^{-1}, while the carbonyl stretch of δ-lactone **12** occurs at 1710 cm^{-1}.

A tribromo δ-lactone (e.g., from bromination of **2**) can aromatize under basic conditions via a series of 1,2-eliminations involving bromide and the internal carboxylate, but aromatization of a tribromo γ-lactone requires 1,4-elimination of the internal carboxylate. When the cuprate-derived substituent is methyl or butyl (but not aryl), then an alternative 1,4-elimination is possible, involving a proton on the substituent. This substituent proton is probably significantly more sterically accessible than the proton that must be removed for aromatization, and the competing 1,4-elimination pathway may explain the poorer yields of **17** and **18**, relative to **2**, from the bromination/dehydrobromination sequence.

(17) Esterification with BF_3: Marshall, J. L.; Erickson, K. C. *Tetrahedron Lett.* **1970**, *11*, 4011.

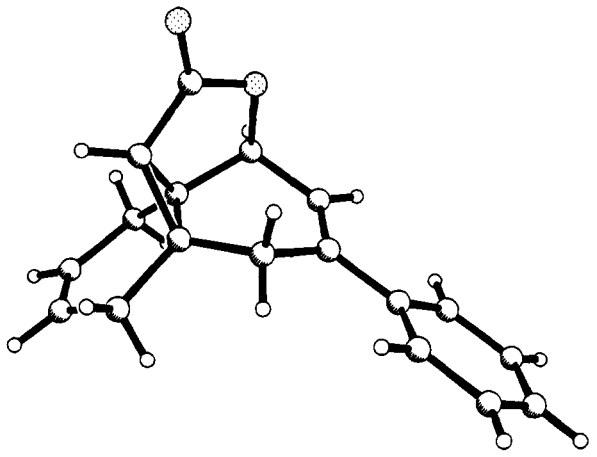
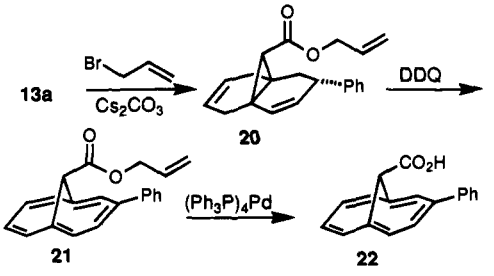


Figure 3. Ball-and-stick representation of the solid state structure of lactone **19**.

Scheme 5



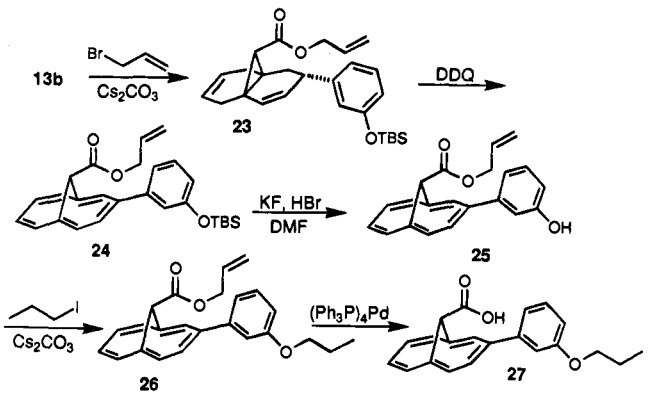
Further Manipulation of Disubstituted 1,6-Methano[10]annulene Derivatives Bearing Aryl Substituents on the Annulene Ring. Our ultimate goal of generating bridged annulene-based contrafacial amphiphiles required that we be able to convert esters like **15** to the corresponding carboxylic acids. Efforts to remove the methyl group under a variety of conditions were unsuccessful; strongly basic conditions were problematic because of competing epimerization, and other approaches failed, perhaps because of steric shielding by the annulene ring. We therefore examined the allyl group for carboxyl protection, since Pd-mediated deprotection[18] can be carried out under neutral conditions and involves attack at a less sterically shielded site.

Treatment with allyl bromide and Cs_2CO_3 efficiently converted acid **13a** to allyl ester **20**, which was then oxidized with DDQ and deprotected with $Pd(PPh_3)_4$ to provide annulene acid **22** (Scheme 5) in 62% overall yield from lactone **12** (the precursor to **13a**). The structure of **22** was confirmed crystallographically.[19] When acid **13b** was subjected to the allylation conditions, the desired ester **23** was produced in 82% yield (Scheme 6), along with 16% of the diallyl derivative resulting from removal of the *tert*-butyldimethylsilyl group followed by

(18) Kunz, H.; Waldmann, H. *Angew. Chem., Int. Ed. Engl.* **1984**, *23*, 71.

(19) Crystallographic data for annulenes **2**, **22**, and **27** may be found in the supplementary material to ref 4.

Scheme 6



phenol alkylation. Ester **23** was oxidized to the corresponding bridged annulene, **24**, with DDQ. Annulene **24** was of interest because the protected phenol provides a site for further modification. After removal of the silyl group with KF/HBr,[20] the phenolic hydroxyl of **25** could be alkylated in high yield with propyl iodide in the presence of Cs_2CO_3, to provide **26**. No evidence of epimerization at the bridge was detected after this reaction. The allyl group was then removed with $Pd(PPh_3)_4$, providing **27**, the structure of which was confirmed crystallographically.[19]

Conclusion. We have developed a route that provides efficient access to derivatives of 1,6-methano[10]annulene bearing substituents on both the bridge and the annulene ring, a substitution pattern that has not previously been reported. The methodology we have described, along with bridged annulene chemistry previously reported by others, should allow construction of a wide variety of previously unavailable bridged annulenes. Our own interests are focused on versions in which the bridge substituent is polar; preliminary data indicate that these "contrafacial amphiphiles" have unique solution properties, relative to more traditional amphiphile topologies.[4] Further studies on these unusual amphiphiles are underway.

Experimental Section

Materials and Methods. Reagents were purchased from Aldrich Chemical Co. unless otherwise noted. Solvents employed were reagent grade. THF and ether were distilled from sodium/benzophenone under N_2; CH_2Cl_2, CH_3CN, toluene, and benzene were distilled from CaH_2 under N_2. Methanol designated as absolute was used from freshly opened bottles of commercially dried solvent. *n*-Hexane used for chromatography was distilled. Column chromatography was performed on 230–400-mesh silica from EM Science. Thin-layer chromatography was performed using silica gel 60 F-254 plates (EM).

For procedures requiring anhydrous conditions, all glassware was flame dried under vacuum and flushed with N_2 upon cooling. Glassware were equipped with septa, and reagent transfers were carried out with syringe and cannula techniques.

Instrumentation. NMR spectra were recorded on Bruker WP-200, WP-270, and AM-500 spectrometers. Tetramethylsilane (TMS) served as an internal standard for compounds not containing silyl groups. For the TMS-trapped acyloin product **7**, the residual solvent peak functioned as the internal standard. Carbon shifts were referenced relative to solvent signals. For carbon NMR spectra, the number of hydrogen atoms on each carbon was determined by DEPT experiments and the results are listed in parentheses following the chemical shifts. Infrared (IR) spectra were obtained on either a Mattson Polaris instrument or a Nicolet 740 infrared spectrometer. Absorbance intensities are given as very strong (vs), strong (s), medium (m), weak (w), and/or broad (br). High-resolution electron-impact mass spectra (HREIMS) were recorded on a Kratos MS-25 spectrometer. Fast atom bombardment mass spectra (FABMS) were recorded on a VG Analytical ZAB-2F spectrometer. Melting points (mp) were determined on a Thomas Hoover apparatus and are uncorrected.

Dimethyl 1,4,4a,5,8,8a-Hexahydronaphthalene-*cis*-4a,8a-dicarboxylate (6). A solution of diacid **5**[21] (11.1 g, 50 mmol) and $(CH_3O)_2SO_2$ (14.2 mL, 150 mmol) in 750 mL of dry CH_3CN was stirred in the presence of K_2CO_3 under N_2 for 3 h. The cloudy mixture was then treated with 100 mL of 1 M HCl, and the CH_3CN was removed on a rotary evaporator. The residue was extracted with three 150-mL portions of CH_2Cl_2; the extracts were combined, dried over $MgSO_4$, and concentrated to a colorless crystalline solid (12.7 g, quantitative yield): mp 100 °C (lit.[21] mp 100 °C); ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 2.21–2.61 (br m, 8H, CH_2), 3.68 (s, 6H, CH_3), 5.50–5.64 (m, 4H, CH); ^{13}C-NMR ($CDCl_3$, 125 MHz) δ 33.49 (CH_2), 44.41 (C), 51.78 (CH_3), 123.80 (CH), 175.77 (C); IR (KBr) 2952 (s), 2935 (s), 1732 (vs), 1273 (s), 1190 (vs), 671 (s) cm^{-1}; HREIMS *m/z* 250.1203 (calcd for $C_{14}H_{18}O_4$ 250.1205).

12-Hydroxy-11-oxotricyclo[4.4.2.0^{1,6}]dodeca-3,8-diene (8). Sodium (115 mg, 5 mmol) and potassium (115 mg, 2.9 mmol) were added to 20 mL of refluxing benzene under N_2. After the amalgam had formed, the mixture was cooled to room temperature while vigorous stirring was maintained. The solvent was then removed from the finely dispersed metal and replaced with 10 mL of dry ether. A solution of **6** (250 mg, 1 mmol) and $(CH_3)_3SiCl$ (508 μL, 4 mmol) in 5 mL of ether was then added dropwise, resulting in a deep purple mixture. After 4 h at room temperature, the mixture was filtered through a glass frit under N_2, and the residue was washed with three 15-mL portions of dry ether. Concentration of the filtrate on a rotary evaporator afforded 330 mg of a colorless liquid, 11,12-bis((trimethylsilyl)oxy)-tricyclo[4.4.2.0^{1,6}]dodeca-3,8,11-triene (**7**) (quantitative yield): ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.19 (s, 18H, CH_3), 1.73–2.10 (m, 8H, CH_2), 5.70 (m, 4H, CH); ^{13}C-NMR ($CDCl_3$, 125 MHz) δ 0.78 (CH_3), 31.13 (CH_2), 45.93 (C), 121.25 (C), 126.71 (CH).

This material was not further characterized but was carried directly to the next step. Stirring **7** (334 mg, 1 mmol) for 20 h at room temperature in 20 mL of degassed CH_3OH yielded 182 mg (96%) of a crystalline solid (**8**) upon removal of the solvent: mp 77–79 °C (lit.[8] mp 81.5–82.5 °C); ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 1.87–2.71 (m, 8H, CH_2), 3.06 (br d, 1H, 5.9 Hz, OH), 4.48 (d, 1H, 5.9 Hz, C*H*OH), 5.43–5.97 (m, 4H, CH); ^{13}C-NMR ($CDCl_3$, 125 MHz) δ 28.25 (CH_2), 29.82 (CH_2), 30.69 (CH_2), 33.57 (CH_2), 41.73 (C), 61.06 (C), 85.23 (CH), 127.27 (CH), 127.47 (CH), 127.57 (CH), 129.07 (CH), 216.76 (C); IR (KBr) 3600–3200 (br), 1778 (s), 1136 (m), 684 (s) cm^{-1}; HREIMS *m/z* 190.0995 (calcd for $C_{12}H_{14}O_2$ 190.0994).

11-Oxotricyclo[4.4.2.0^{1,6}]dodeca-3,8-dienyl 12-Methanesulfonate (9). Methanesulfonyl chloride (237 μL, 3 mmol) was added dropwise to a solution of **8** (380 mg, 2 mmol) and triethylamine (358 μL, 3 mmol) in 20 mL of CH_2Cl_2 at 0 °C. After 3 h, the solution was warmed to room temperature and washed successively with 15-mL aliquots of water, 1 M HCl, saturated aqueous $NaHCO_3$, and saturated aqueous NaCl. The organic phase was dried over $MgSO_4$, and the solvent was removed on a rotary evaporator to yield 530 mg of a slightly yellow oil, which was purified by column chromatography (silica, 28% ethyl acetate in hexane), providing 517 mg of a white solid (96%): mp 87–88 °C; ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 1.95–2.65 (m, 8H, CH_2), 3.13 (s, 3H, SCH_3), 5.17 (s, 1H, C*H*OMs), 5.77–6.07 (m, 4H, CH); ^{13}C-NMR ($CDCl_3$, 125 MHz) δ 28.69 (CH_2), 29.78 (CH_2), 30.66 (CH_2), 32.77 (CH_2), 38.58 (CH_2), 41.93 (C), 62.09 (C), 85.94 (CH), 127.50 (CH), 127.52 (CH), 127.55 (CH), 127.93 (CH); IR (KBr) 1789 (vs), 1358 (vs), 1187 (s), 697 (s), 688 (s) cm^{-1}; HREIMS *m/z* 269.0854 (calcd for $C_{13}H_{17}O_4S$ (M + H) 269.0802).

[4.4.1]Propella-3,8-diene-11-carboxylic Acid (10). To a solution of LiOH (4.30 g, 102 mmol) in 300 mL of 50% aqueous THF was added solid **9** (9.16 g, 34.1 mmol). The solid slowly dissolved, leaving a slightly yellow solution. After 24 h at room temperature, THF was removed on a rotary evaporator, and the aqueous mixture was diluted with 50 mL of water and washed with three 50-mL portions of ether. Acidification of the aqueous layer to pH 1 by the dropwise addition of concentrated HCl resulted in a white precipitate, which was extracted

(20) Sinhababu, A. K.; Kawase, M.; Borchardt, R. T. *Synthesis* **1988**, 710.

(21) Spur, P. R.; Hamon, D. P. G. *J. Am. Chem. Soc.* **1983**, *105*, 4734.

into CH_2Cl_2 using three 50-mL portions. The organic phases were combined, dried over $MgSO_4$, and concentrated on a rotary evaporator to yield 6.25 g of a white solid (96%): mp 131−132 °C (lit.[10] mp 134.5−135.5 °C); ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 1.86 (s, 1H, C*H*CO_2H), 2.12−2.62 (m, 8H, CH_2), 5.47−5.58 (m, 4H, CH); ^{13}C-NMR ($CDCl_3$, 125 MHz) δ 25.13 (C), 25.66 (CH), 29.05 (CH_2), 32.12 (CH_2), 124.29 (CH), 124.88 (CH), 177.92 (C); IR (KBr) 3300−2400 (br), 1693 (s), 1291 (vs), 1244 (vs), 929 (s), 683 (vs), 649 (s) cm^{-1}; HREIMS *m/z* 190.0988 (calcd for $C_{12}H_{14}O_2$ 190.0994).

11-Carboxy-1,6-methano[10]annulene (2). Bromine (52 μL, 1 mmol) was added dropwise to a stirred solution of **10** (96 mg, 0.5 mmol) in 5 mL of dry CH_2Cl_2 at 0 °C. After 10 min, the solvent was removed from the orange solution, leaving an isomeric mixture of tribromo lactones as a slightly yellow solid foam (212 mg, quantitative yield): ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 2.11−3.16 (m, 9H, CH_2 and C*H*CO_2), 4.41−4.61 (m, 4H, CHBr, and CH_2C*H*O); IR (KBr) 1721 (s), 1716 (s), 1221 (vs), 1189 (s), 1075 (s), 1055 (vs), 541 (vs) cm^{-1}; HREIMS *m/z* 425.8467 (44%), 427.8443 (100%), 429.8392 (117%), 431.8455 (32%) (calcd for $C_{12}H_{13}O_2Br_3$ 425.8466 (34%), 427.8447 (100%), 429.8427 (99%), 431.8413 (33%)).

This material was not further purified but was carried directly to the next step. Solid *t*-BuOK (140 mg, 1.25 mmol) was added to a solution of the tribromo lactones (108 mg, 0.25 mmol) in 20 mL of dry THF at 0 °C. After 2.5 h, 10 mL of water was added, the THF was removed on a rotary evaporator, and the residue was diluted with 30 mL of water. This solution was washed with two 20-mL portions of ether, acidified to pH 1 with concentrated HCl, and then extracted with five 25-mL aliquots of ether. The combined extracts were dried over $MgSO_4$ and concentrated, yielding the desired product as a yellow solid, 43 mg (93%): mp 235−238 °C dec (lit.[10] mp 241−242 °C); ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.52 (s, 1H, C*H*CO_2H), 6.99−7.14 (AA′BB′, 4H, Ar CH), 7.44−7.55 (AA′BB′, 4H, Ar CH); ^{13}C-NMR ($(CD_3)_2SO$, 125 MHz) δ 48.35 (CH), 115.47 (C), 125.03 (CH), 126.03 (CH), 128.21 (CH), 129.52 (CH), 167.58 (C); IR (KBr) 3200−3400 (br), 1700 (vs), 1270 (m), 775 (m), 740 (m) cm^{-1}; HREIMS *m/z* 186.0677 (calcd for $C_{12}H_{10}O_2$ 186.0681).

11-Carbomethoxy-1,6-methano[10]annulene (11). A solution of $(CH_3O)_2SO_2$ (30 μL, 0.32 mmol) and **2** (40 mg, 0.21 mmol) in 5 mL of CH_3CN was stirred in the presence of K_2CO_3 (44 mg, 0.32 mmol) under N_2 for 3 h at room temperature. The reaction mixture was then treated with 20 mL of 1 M HCl, followed by extraction with three 25-mL portions of CH_2Cl_2. The extracts were combined, dried over $MgSO_4$, and concentrated to a slightly yellow oil, which crystallized upon standing (43 mg, quantitative yield): mp 114−116 °C (lit.[10] mp 125.5−126 °C); ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.50 (s, 1H, C*H*CO_2-CH_3), 3.29 (s, 3H, CH_3), 6.96−7.13 (AA′BB′, 4H, Ar CH), 7.25−7.56 (AA′BB′, 4H, Ar CH); ^{13}C-NMR ($CDCl_3$, 125 MHz) δ 48.49 (CH), 51.32 (CH_3), 115.43 (C), 125.38 (CH), 126.36 (CH), 128.04 (CH), 129.44 (CH), 167.50 (C); IR (KBr) 2940 (w), 1725 (vs), 1225 (s), 765 (s) cm^{-1}; HREIMS *m/z* 200.0836 (calcd for $C_{13}H_{12}O_2$ 200.0837).

4-*exo*-Hydroxy[4.4.1]propella-2,8-diene-11-carboxylic Acid Lactone (12). A solution of KI (8.3 g, 50 mmol) and I_2 (3.8 g, 15 mmol) in 50 mL of water was added to a solution of carboxylic acid **10** (1.90 g, 10 mmol) in 100 mL of 0.5 M aqueous $NaHCO_3$, and the resulting mixture was allowed to stand for 24 h in the dark. Enough $Na_2S_2O_3$ was then added to decolorize the mixture, followed by 50 mL of CH_2Cl_2. The two layers were separated, and the aqueous phase was extracted with CH_2Cl_2. The combined organic layers were dried over $MgSO_4$ and concentrated on a rotary evaporator, to yield 3-*endo*-iodo-4-*exo*-hydroxy[4.4.1]propell-8-ene-11-carboxylic acid lactone as a yellow solid, 2.99 g (95%): mp 112−113 °C; ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 2.09 (s, 1H, CHCO), 2.10 (m, 2H, CH_2), 2.40 (m, 4H, allylic CH_2), 2.90 (br d, 1H, 14.4, allylic CH), 3.20 (dd, 1H, 17.4, 8.7, allylic CH), 4.63 (m, 2H, CHI, CHO), 5.58 (m, 2H, olefinic CH); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 19.69 (CH), 25.98 (CH_2), 28.12 (C), 28.32 (C), 28.85 (CH_2), 28.86 (CH), 31.97 (CH_2), 38.33 (CH_2), 76.98 (CH), 122.62 (CH), 122.88 (CH), 170.64 (C); IR (KBr) 3200−2400 (br), 1714 (vs), 1369 (s), 1053 (m), 1000 (m) cm^{-1}; HREIMS *m/z* 315.9977 (calcd for $C_{12}H_{13}O_2I$ 315.9956).

DBU (1.23 mL, 8.2 mmol) was added to a solution of the iodo lactone (1.085 g, 3.43 mmol) in 50 mL of dry benzene under N_2 at room temperature. After 24 h, the precipitated solid was removed via filtration through Celite, and the filtrate was concentrated to a brown residue, which was purified by column chromatography (silica, 2:1 hexane/ethyl acetate) to provide 627 mg of a white crystalline solid (**12**) (97%): mp 118−119 °C; ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 1.51 (dd, 1H, 13.9, 1.9), 2.09 (dd, 1H, 13.9, 3.9), 2.33−2.81 (m, 5H, $CHCO_2$ and allylic CH_2), 4.81 (m, 1H, CHO), 5.61 (m, 2H, vinylic H), 6.14 (m, 2H, vinylic H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 26.06 (C), 27.57 (CH_2), 27.88 (CH_2), 29.52 (CH_2), 31.53 (C), 33.42 (CH_2), 68.87 (CH), 122.89 (CH), 123.15 (CH), 124.44 (CH), 135.43 (CH), 169.73 (C); IR (KBr) 3037 (m), 1710 (vs), 1659 (s), 1361 (s), 1035 (m), 780 (s) cm^{-1}; HREIMS *m/z* 188.0835 (calcd for $C_{12}H_{12}O_2$ 188.0837).

4-Phenyl[4.4.1]propella-2,8-diene-11-carboxylic Acid (13a). Phenyllithium (2.12 mL, 1.8 M in cyclohexane/ether, 3.81 mmol) was added dropwise to a stirred slurry of CuBr·$S(CH_3)_2$[22] (380 mg, 1.85 mmol) in 3 mL each of methyl sulfide and ether under N_2 at −78 °C. After 10 min, a solution of lactone **12** (188 mg, 1 mmol) in 3 mL of THF, also at −78 °C, was transferred by cannula into the yellow cuprate solution. The resulting yellow mixture was stirred for 3 h at this temperature, the cooling was then removed, and the mixture was stirred an additional 8 h. The now green mixture was quenched with 20 mL of saturated aqueous NH_4Cl and extracted three times with 20 mL of ether. The combined extracts were washed with three 20-mL portions of saturated aqueous NH_4Cl, dried over $MgSO_4$, and concentrated to a slightly yellow crystalline solid, 318 mg (97%): mp 150 °C dec; ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 1.67 (dd, 1H, 14.4, 5.9), 1.85 (m, 1H, allylic H), 2.11 (s, 1H, $CHCO_2$), 2.31−2.51 (m, 2H, allylic CH_2), 2.63 (m, 1H, allylic H), 2.72 (dd, 1H, 14.4, 7.8), 3.53 (m, 1H, H4), 5.42−5.63 (m, 2H, vinylic H), 5.88 (app s, 2H, vinylic H), 7.14−7.31 (m, 5H, Ph H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 26.79 (C), 28.07 (C), 29.70 (CH_2), 30.76 (CH), 32.99 (CH_2), 34.53 (CH_2), 39.21 (CH), 123.64 (CH), 124.23 (CH), 126.06 (CH), 127.29 (CH), 127.64 (CH), 128.38 (CH), 128.69 (CH), 145.30 (C), 177.50 (C); IR (KBr) 3500−2400 (br), 3020 (vs), 2928 (vs), 1695 (vs), 1422 (vs), 1304 (s), 1216 (s), 1210 (vs), 1204 (s), 1174 (s), 797 (s), 764 (vs), 711 (vs) cm^{-1}; HREIMS *m/z* 266.1297 (calcd for $C_{18}H_{18}O_2$ 266.1307).

Methyl 4-Phenyl[4.4.1]propella-2,8-diene-11-carboxylate (14a) was prepared from carboxylic acid **13a** via a procedure analogous to that used for **11**. The crude product was purified by column chromatography (silica, 10% ethyl acetate in hexane) to afford the desired compound as a colorless oil (84%): ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 1.65 (dd, 1H, 14.3, 6.5), 1.90 (m, 1H, allylic H), 2.08 (s, 1H, $CHCO_2$), 2.32−2.45 (m, 2H, allylic CH_2), 2.64 (m, 1H, allylic H), 2.68 (dd, 1H, 14.3, 7.9), 3.49 (m, 1H, H4), 3.66 (s, 3H, CO_2CH_3), 5.41−5.62 (m, 2H, vinylic H), 5.85 (app s, 2H, vinylic H), 7.14−7.32 (m, 5H, Ph H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 26.02 (C), 26.86 (C), 29.63 (CH_2), 30.79 (CH), 32.83 (CH_2), 34.75 (CH_2), 39.23 (CH), 51.23 (CH_3), 123.68 (CH), 124.23 (CH), 125.97 (CH), 127.61 (CH), 127.67 (CH), 128.31 (CH), 129.90 (CH), 145.47 (C), 171.46 (C); IR (film) 1731 (vs), 1197 (m), 1167 (m), 1019 cm^{-1}; HREIMS *m/z* 280.1455 (calcd for $C_{19}H_{20}O_2$ 280.1463).

***syn*-11-Carbomethoxy-3-phenyl-1,6-methano[10]annulene (15).** A solution of **14a** (140 mg, 0.50 mmol) and DDQ (170 mg, 0.75 mmol) in 25 mL of dry dioxane was stirred at 60−70 °C for 41 h, during which time the orange solution lightened and a precipitate appeared. More DDQ (170 mg, 0.75 mmol) was then added, and the resulting red solution was stirred at reflux for 24 h. After the solution was cooled to room temperature, a precipitate formed which was removed via filtration over a small amount of silica. The solid was rinsed with 30 mL of CH_2Cl_2, and the rinsings were added to the filtrate, which was concentrated to a dark oil. This oil was chromatographed (silica, 10% ethyl acetate in hexane), yielding 101 mg of a slightly yellow solid (73%). Further chromatography of this material (silica, 2% ethyl acetate in hexane) provided 83 mg (60%) of **15**: mp 117−119 °C dec; ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 0.71 (s, 1H, $CHCO_2$), 3.29 (s, 3H, CO_2-CH_3), 7.11 (m, 2H), 7.37 (d, 1H, 9.6), 7.41 (app tt, 7.41, 1.3), 7.46−7.49 (m, 2H), 7.54−7.57 (m, 2H), 7.58 (br s, 1H), 7.62 (m, 1H), 7.62−7.64 (m, 2H); ^{13}C-NMR ($CDCl_3$, 125 MHz) δ 48.87 (CH), 51.43 (CH_3), 115.30 (C), 115.65 (C), 126.04 (CH), 126.26 (CH), 126.51 (CH), 127.12 (CH), 128.18 (CH), 128.51 (CH), 128.56 (2CH), 128.64 (C), 129.66 (CH), 130.23 (CH), 139.41 (C), 167.52 (C); IR (KBr) 1736 (vs), 1231

(22) Wuts, P. G. M. *Synth. Commun.* **1981**, *11*, 139.

(vs), 1175 (s), 765 (vs), 703 (s) cm^{-1}; HREIMS *m/z* 276.1151 (calcd for $C_{19}H_{16}O_2$ 276.1150).

A second fraction contained 7 mg (5%) of the bridgehead epimer, *anti*-11-carbomethoxy-3-phenyl-1,6-methano[10]annulene, a pale yellow solid: ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 0.77 (s, 1H, $CHCO_2$), 3.35 (s, 3H, CO_2CH_3), 6.96−7.02 (m, 2H), 7.38 (app t, 1H), 7.44−7.48 (m, 3H), 7.46 (br s, 1H), 7.55 (br d, 1H, 9.0), 7.56−7.60 (m, 2H), 7.63−7.66 (m, 2H); IR (film) 2952 (w), 2924 (w), 1735 (vs), 1448 (m), 1210 (s), 1055 (s) cm^{-1}; HREIMS *m/z* 276.1139 (calcd for $C_{19}H_{16}O_2$ 276.1150).

3-Bromo((*tert*-butyldimethylsilyl)oxy)benzene. Imidazole (8.2 g, 120 mmol) was added to a solution of 3−bromophenol in 200 mL of CH_3CN, and a N_2 atmosphere was established. Within minutes, a white precipitate formed. The resulting mixture was stirred for 24 h before being filtered over Celite. The filtrate was then concentrated, and the brown oil was chromatographed on silica, eluting with 20:1 hexane/ethyl acetate. The desired product, a colorless liquid, was obtained in quantitative yield (29.87 g): ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.23 (s, 6H, $Si(CH_3)_2$), 100 (s, 9H, $C(CH_3)_3$), 6.76−6.84 (m, 1H, Ar H), 7.04 (m, 1H, Ar H), 7.09−7.14 (m, 2H, Ar H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 1.06 (CH_3), 18.13 (C), 25.59 (CH_3), 118.76 (CH), 122.50 (C), 123.52 (CH), 124.47 (CH), 130.37 (CH), 156.49 (C); IR (film) 2955 (s), 2930 (s), 2859 (s), 1589 (vs), 1568 (s), 1474 (vs), 1422 (m), 1294 (s), 1270 (vs), 1239 (vs), 933 (vs) cm^{-1}; HREIMS *m/z* 286.0407 (88%), 288.0359 (100%) (calcd for $C_{12}H_{19}OSiBr$ 286.0389 (97%), 288.0370 (100%)).

4-(3-((*tert*-Butyldimethylsilyl)oxy)phenyl)[4.4.1]propella-2,8-diene-11-carboxylic Acid (13b). To a solution of 3-bromo-((*tert*-butyldimethylsilyl)oxy)benzene (6.898 g, 24 mmol) in 20 mL of ether under a N_2 atmosphere, at 0 °C, was added BuLi (13.62 mL, 1.6 M in hexanes, 21.8 mmol) dropwise. After 70 min, the resulting tan solution was cooled to −45 °C and cannulated onto a slurry of $CuBrS(CH_3)_2$[22] (2.240 g, 10.9 mmol) in 10 mL each of methyl sulfide and ether under N_2 at −45 °C. After 45 min, the dark solution was cooled to −78 °C, and lactone **12** was added via cannula as a solution in 20 mL of THF, precooled to −78 °C. After 2 h at −78 °C, the reaction mixture was allowed to warm to room temperature slowly and was stirred for 18 h. The reaction mixture was quenched and worked up as described for **13a** to provide a yellow oil (6.57 g, quantitative crude yield).

In general, crude acid **13b** was esterified before further purification. However, a small amount was purified for characterization via column chromatography on silica, eluting with 10:1 hexane/ethyl acetate. The solid so obtained was crystallized by the slow evaporation of ethyl acetate/hexane: mp 96−98 °C dec; ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.18 (s, 6H, $Si(CH_3)_2$), 0.97 (9H, $C(CH_3)_3$), 1.67 (dd, 1H, 14.4, 5.3), 1.81−1.90 (m, 1H, allylic H), 2.09 (s, 1H, $CHCO_2$), 2.22−2.39 (m, 2H, allylic CH_2), 2.59 (m, 1H, allylic H), 2.72 (dd, 1H, 14.4, 7.8), 3.46 (m, 1H, H4), 5.47−5.61 (m, 2H), 5.87 (br s, 2H), 6.64−6.68 (m, 2H, Ar H), 6.78 (br d, 1H, 7.7), 7.13 (m, 1H, Ar H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 0.94 (CH_3), 18.13 (C), 25.65 (CH_3), 26.72 (C), 28.25 (C), 29.69 (CH_2), 30.59 (CH), 33.02 (CH_2), 34.22 (CH_2), 38.94 (CH), 119.53 (CH), 120.80 (CH), 123.62 (CH), 124.28 (CH), 127.22 (CH), 129.18 (CH), 130.40 (CH), 146.80 (CH), 155.67 (C), 177.62 (C); IR (KBr) 3600−2400 (br), 1688 (vs), 1599 (s), 1582 (s), 1481 (vs), 1471 (s), 1462 (s), 1442 (s), 1280 (s), 1256 (s), 1218 (vs), 927 (s) cm^{-1}; HREIMS *m/z* 396.2118 (calcd for $C_{24}H_{32}O_3Si$ 396.2121).

Methyl 4-(3-((*tert*-Butyldimethylsilyl)oxy)phenyl)[4.4.1]propella-2,8-diene-11-carboxylate (14b) was prepared from crude acid **13b** via a procedure similar to that used to prepare **11**. The crude product was purified by column chromatography (silica, 20:1 hexane/ethyl acetate) to afford the desired compound as a colorless oil (94% from lactone **12**): ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.17 (s, 6H, $Si(CH_3)_2$), 0.97 (9H, $C(CH_3)_3$), 1.65 (dd, 1H, 14.4, 5.9), 1.84−1.92 (m, 1H, allylic H), 2.07 (s, 1H, $CHCO_2$), 2.34−2.56 (m, 2H, allylic CH_2), 2.58 (m, 1H, allylic H), 2.67 (dd, 1H, 14.1, 8.0), 3.39−3.47 (m, 1H), 3.65 (s, 3H, CO_2CH_3), 5.47−5.60 (m, 2H), 5.85 (app s, 2H, 6.63−6.68 (m, 2H, Ar H), 6.78 (br d, 1H), 7.13 (m, 1H, Ar H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 0.96 (CH_3), 18.10 (C), 25.63 (CH_3), 25.99 (C), 27.04 (C), 29.67 (CH_2), 30.68 (CH), 33.90 (CH_2), 34.50 (CH_2), 39.05 (CH), 51.23 (CH_3), 117.60 (CH), 119.52 (CH), 120.74 (CH), 123.72 (CH), 124.32 (CH), 127.64 (CH), 129.15 (CH), 129.95 (CH), 147.07 (C), 155.63 (C), 171.57 (C); IR (film) 3020 (m), 2953 (s), 2930 (s), 2895 (m), 2858 (s), 1734 (vs), 1600 (m), 1588 (m), 1482 (s), 1437 (s), 1279 (s), 1258 (s), 1164 (vs), 889 (s) cm^{-1}; HREIMS *m/z* 410.2274 (calcd for $C_{25}H_{34}O_3Si$ 410.2277).

***syn*-11-Carbomethoxy-3-(3-((*tert*-butyldimethylsilyl)oxy)phenyl)-1,6-methano[10]annulene (16)** was prepared from **14b** via a procedure similar to that used to prepared **15**. The crude product was chromatographed (silica, 10:1 ethyl acetate/hexane) to yield a yellow solid (81%) that HPLC indicated to be an 89:11 mixture of two epimers. Further chromatography provided the desired compound (58%) and a minor isomer (5%) which was shown to be the bridgehead epimer.

syn-Isomer **16**: mp 122−124 °C dec; ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 0.31 (s, 6H, $Si(CH_3)_2$), 0.76 (s, 1H, $CHCO_2$), 1.07 (s, 9H, $C(CH_3)_3$), 3.34 (s, 3H, CO_2CH_3), 6.90 (ddd, 1H, 8.0, 3.5, 2.0), 7.09−7.15 (m, 2H), 7.12 (m, 1H), 7.22 (m, 1H), 7.32 (dd, 1H, 9.0, 8.0), 7.33 (d, 1H, 8.1), 7.53−7.56 (m, 2H), 7.56 (br s, H2), 7.61 (br d, 1H, 9.7); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 0.93 (CH_3), 18.18 (C), 25.67 (CH_3), 48.80 (CH), 51.45 (CH_3), 115.26 (C), 115.88 (C), 118.94 (CH), 120.52 (CH), 121.77 (CH), 125.29 (CH), 125.61 (CH), 126.45 (CH), 127.93 (CH), 128.05 (CH), 128.77 (CH), 129.41 (CH), 130.15 (CH), 140.02 (C), 145.37 (C), 155.76 (C), 167.58 (C); IR (KBr) 2955 (s), 2949 (s), 1739 (vs), 1288 (s), 1256 (s), 1253 (s), 1231 (s), 1219 (s), 840 (s) cm^{-1}; HREIMS *m/z* 406.1965 (calcd for $C_{25}H_{36}O_3Si$ 406.1964).

anti-Isomer **29**: mp 88−92 °C dec; ^{1}H-NMR ($CDCl_3$, 500 MHz) δ 0.24 (s, 6H, $Si(CH_3)_2$), 0.74 (s, 1H, $CHCO_2$), 1.01 (s, 9H, $C(CH_3)_3$), 3.33 (s, 3H, CO_2CH_3), 6.84 (ddd, 1H, 8.0, 2.4, 1.0), 6.93−6.99 (m, 2H), 7.10 (t, 1H, 2.1), 7.20−7.24 (m, 1H), 7.28 (app t, 1H, 7.9), 7.40 (d, 1H, 9.0), 7.43 (br s, 1H), 7.52 (br d, 10.0), 7.53−7.58 (m, 2H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 0.83 (CH_3), 18.14 (C), 25.64 (CH_3), 48.74 (CH), 51.40 (CH_3), 115.18 (C), 115.61 (C), 118.76 (CH), 120.31 (CH), 121.64 (CH), 125.98 (CH), 126.24 (CH), 126.37 (CH), 126.50 (CH), 128.13 (CH), 129.33 (CH), 129.64 (CH), 130.15 (CH), 139.09 (C), 145.55 (C), 155.63 (C), 167.70 (C); IR (KBr) 2948 (s), 2938 (m), 2926 (m), 1745 (vs), 1573 (s), 1482 (s), 1251 (s), 1210 (s) cm^{-1}; HREIMS *m/z* 406.1963 (calcd for $C_{25}H_{36}O_3Si$ 406.1964).

4-Methyl[4.4.1]propella-2,8-diene-11-carboxylic Acid (13d). $(CH_3)_2$-CuLi was formed by the slow addition of CH_3Li (3.41 mL, 0.88 M in hexanes, 3 mmol) to a solution of $CuBrS(CH_3)_2$[22] (308 mg, 1.5 mmol) in 3 mL each of methyl sulfide and ether under N_2 at 0 °C. The resulting colorless solution was stirred for 5 min before being treated with a solution of lactone **12** (188 mg, 1 mmol) in 5 mL of THF, also at 0 °C. After 2 h at this temperature, the yellow mixture was allowed to warm to room temperature and stirred an additional 2 h. The reaction was quenched and worked up as described for **13a** to provide the desired compound as a white crystalline solid, 188 mg (92%): mp 118−120 °C; ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 1.00 (d, 3H, 6.9, $CHCH_3$), 1.31 (dd, 1H, 13.7, 6.0), 2.05 (s, 1H, $CHCO_2CH_3$), 2.13−2.47 (m, 6H, CH_2 and $CHCH_3$), 5.55 (m, >2H, vinylic H), 5.64 (part of AB portion of ABX, <2H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 21.71 (CH_3), 27.79 (2C), 27.87 (CH), 29.79 (CH_2), 30.76 (CH), 33.21 (CH_2), 33.47 (CH_2), 124.01 (CH), 124.16 (CH), 125.58 (CH), 133.63 (CH), 177.75 (C); IR (KBr) 3500−2400 (br), 1687 (vs), 1226 (vs), 1217 (vs), 682 (vs) cm^{-1}; HREIMS *m/z* 204.1135 (calcd for $C_{13}H_{16}O_2$ 204.11503).

Methyl 4-Methyl[4.4.1]propella-2,8-diene-11-carboxylate (14d). A solution of acid **13d** (50 mg, 0.24 mmol) and BF_3·Et_2O (45 μL, 0.37 mmol) in 10 mL of CH_3OH was refluxed for 24 h, and then 10 mL of 1 M HCl was added. The mixture was extracted with three 25-mL portions of CH_2Cl_2; the extracts were then combined, dried over $MgSO_4$, and concentrated to a colorless oil, 49 mg (94%): ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 1.00 (d, 3H, 7.0, $CHCH_3$), 1.31 (dd, 1H, 13.9, 6.9), 2.03 (s, 1H, $CHCO_2$), 2.13−2.26 (m, 3H, $CHCH_3$ and CH_2), 2.39 (dd, 1H, 13.9, 7.3), 2.48−2.60 (m, 2H, CH_2), 3.61 (s, 3H, CO_2CH_3), 5.55−5.58 (m, >2H, vinylic H), 5.65 (part of AB portion of ABX, <2H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz), δ 21.82 (CH_3), 26.19 (C), 26.64 (C), 27.81 (CH), 29.72 (CH_2), 30.68 (CH), 33.28 (CH_2), 33.45 (CH_2), 51.17 (CH_3), 124.03 (CH), 124.21 (CH), 126.13 (CH), 132.99 (CH), 171.48 (C); IR (film) 3489 (m), 2953 (m), 2926 (m), 2885 (m), 2876 (m), 1733 (vs), 1436 (m), 1198 (s) cm^{-1}; HREIMS *m/z* 218.1296 (calcd for $C_{14}H_{18}O_2$ 218.1307).

***syn*-11-Carboxy-3-methyl-1,6-methano[10]annulene (18).** Bromine (560 μL, 10.8 mmol) was added dropwise to a solution of carboxylic acid **13d** (1.107 g, 5.4 mmol) in 30 mL of CH_2Cl_2 under N_2 at 0 °C. After 20 min, the solvent was removed on a rotary evaporator, leaving the isomeric mixture of tribromo lactones as a tan

foam, 2.390 g (quantitative crude yield): ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 1.02 (d, 3H, 5.9, $CHCH_3$), 1.50−3.20 (m, 8H, $CHCO_2$, $CHBrCH_2$, and $CHBrCH$), 4.00−4.50 (m, 3H, CHBr), 4.76 (d, 1H, 3.9, CHO); IR (film) 1773−1733 (br, vs), 1221 (vs), 1189 (s), 1075 (s), 1055 (vs), 990 (vs) cm^{-1}. This material was carried on without further purification.

A solution of DBU (7.27 mL, 49 mmol) and the tribromo lactone mixture (2.3 g, 5.4 mmol) in 70 mL of dry dioxane was heated at reflux for 64 h under N_2. The reaction mixture was allowed to cool to room temperature and was concentrated on a rotary evaporator to afford a black residue, which was stirred in 100 mL of saturated aqueous $NaHCO_3$ for 2 h. The aqueous mixture was then washed with three 30-mL portions of ether, acidified to pH 1, and extracted with three 75-mL aliquots of ether. The combined extracts were dried over K_2CO_3 and concentrated to a light yellow solid, 516 mg (48%): mp 156−158 °C dec; ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.51 (s, 1H, $CHCO_2$), 2.45 (s, 3H, CH_3), 6.83 (d, 1H, 9.8), 7.08 (m, 2H), 7.23 (d, 1H, 1.3), 7.32 (m, 3H); ^{13}C-NMR ($CDCl_3$, 125 MHz) δ 25.35 (CH_3), 48.58 (CH), 113.11 (2 C), 125.98 (CH), 126.22 (CH), 126.48 (CH), 127.88 (CH), 129.31 (CH), 129.44 (CH), 135.44 (C), 172.81 (C); IR (KBr) 3400−2400 (br), 1704 (vs), 1266(s), 751(s) cm^{-1}; HREIMS *m/z* 200.0837 (calcd for $C_{13}H_{12}O_2$ 200.0837).

Methyl 4-Butyl[4.4.1]propella-2,8-diene-11-carboxylate (14c). Butyllithium (1.43 mL, 2.1 M in hexanes, 3.0 mmol) was added dropwise to a stirred slurry of $CuBrS(CCH_3)_2$[22] (308 mg, 1.5 mmol) in 3 mL each of methyl sulfide and ether under N_2 at −78 °C, resulting in the formation of a deep red solution. After 10 min, a solution of lactone **12** (188 mg, 1 mmol) in 5 mL of THF, also at −78 °C, was transferred by cannula into the red cuprate solution. The resulting yellow mixture was stirred for 3 h at this temperature. The cooling bath was removed, and the mixture was stirred for an additional 18 h. The reaction was quenched and worked up as described for **13a** to provide 4-butyl[4.4.1]propella-2,8-diene-11-carboxylic acid (**13c**) in 74% crude yield: ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.89 (m, 3H, CH_3), 1.21−1.35 (m, 6H, $CH_2CH_2CH_2$), 1.40 (dd, 1H, 14.1, 5.7, H5a), 2.05 (s, 1H, $CHCO_2$), 2.13−2.24 (m, 3H), 2.39 (dd, 1H, 14.1, 7.2), 2.48−2.60 (m, 2H, CH_2), 5.56 (m, >2H, 2 vinylic H), 5.70 (<2H, part of AB portion of ABX); IR (KBr) 3300−2400 (br), 2927 (s), 1734 (m), 1697 (vs), 1432 (m), 915 (s) cm^{-1}. This material was carried on without further purification.

Carboxylic acid **13c** was converted to **14c** via a procedure similar to that used for **11**; **14c** was obtained in quantitative yield: ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.89 (m, 3H, CH_2CH_3), 1.26−1.31 (m, 6H, $CH_2CH_2CH_2$), 1.36 (dd, 1H, 14.3, 6.4), 2.03 (s, 1H, $CHCO_2$), 2.12−2.26 (m, 3H), 2.37 (dd, 1H, 14.0, 7.2), 2.47−2.59 (m, 2H, allylic CH_2), 3.61 (s, 3H, CO_2CH_3), 5.56 (m, >2H, vinylic H), 5.68 (part of AB portion of ABX, <2H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 14.07 (CH_3), 22.80 (CH_2), 26.62 (C), 26.79 (C), 29.59 (CH_2), 29.73 (CH_2), 30.78 (CH), 31.22 (CH_2), 32.91 (CH), 33.38 (CH_2), 36.12 (CH), 51.22 (CH_3), 124.10 (CH), 124.29 (CH), 126.30 (CH), 132.22 (CH), 171.62 (C); IR (film) 3027 (m), 2955 (s), 2925 (s), 2874 (s), 2857 (s), 2833 (m), 1736 (vs), 1457 (m), 1435 (m), 1164 (s) cm^{-1}; HREIMS *m/z* 260.1774 (calcd for $C_{17}H_{24}O_2$ 260.1776).

***syn*-11-Carboxy-3-butyl-1,6-methano[10]annulene (17).** Bromine (51 μL, 1 mmol) was added dropwise to a solution of carboxylic acid **13d** (121 mg, 0.5 mmol) in 5 mL of CH_2Cl_2 under N_2 at 0 °C. After 30 min, the solvent was removed on a rotary evaporator, leaving the isomeric mixture of tribromo lactones as a yellow foam, 238 mg (98%): ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.85−0.97 (m, 3H, CH_3), 1.26−1.37 (m, 6H, $CH_2CH_2CH_2$), 1.66−3.26 (m, 8H, $CHBrCH_2$, $CHBu$, $CHCO_2$), 4.15−4.54 (m, 3H, CHBr), 4.75 (d, 1H, 4.0, CHO). This tribromo lactone mixture was converted to annulene **18** by treatment with DBU: ^{1}H-NMR ($CDCl_3$, MHz) δ 0.51 (s, 1H, $CHCO_2$), 0.90 (t, 3H, 7.2, CH_3), 1.25−1.60 (m, 4H, CH_2CH_2), 2.66 (t, 2H, 7.5), 6.83 (d, 1H, 9.9), 7.01−7.05 (m, 2H), 7.25 (br s), 7.37−7.41 (m, 3H).

2-*exo*-Hydroxy-4-*endo*-phenyl[4.4.1]propella-3,8-diene-11-carboxylic Acid Lactone (19). 2-*exo*-Hydroxy-3-*endo*-iodo-4-*endo*-phenyl[4.4.1]propell-8-ene-11-carboxylic acid lactone was prepared from carboxylic acid **13a**, via a procedure similar to that used to prepare **12**, in 92% yield: ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 2.25−2.86 (m, 8H, $CHCO_2$, allylic CH_2, and benzylic CH), 4.40 (dd, 1H, 3.3, 3.2, CHI), 4.95 (d, 1H, 3.9, CHO), 5.56−5.64 (m, 2H, vinylic H), 7.23−7.93 (m, 5H, Ph H). Without further purification, this material was treated with DBU under conditions similar to those used for the preparation of **12**. Lactone **19** was obtained as a white crystalline solid. Single crystals were grown by dissolving the solid in hot hexane/ethyl acetate (2:1) and adding enough hexane to cause turbidity. Upon standing overnight, long thin colorless rods formed: mp 123−125 °C dec; ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 2.20−2.44 (m, 2H, allylic H), 2.28 (s, 1H, $CHCO_2$), 2.62−2.83 (m, 2H, allylic H), 2.78 (AB part of ABX, 2H, $J_{AB\ app}$ = 17.8, $J_{AX\ app}$ = 0, $J_{BX\ app}$ = 3.1), 5.02 (d, 1H, 6.2, CHO), 5.46−5.66 (m, 2H), 6.36 (dd, 1H, 6.2, $J_{BX\ app}$ = 3.1), 7.31−7.38 (m, 5H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 24.95 (CH_2), 30.30 (C), 32.12 (CH_2), 32.80 (CH_2), 32.88 (CH), 37.45 (C), 75.70 (CH), 120.46 (CH), 123.27 (CH), 124.08 (CH), 125.50 (CH), 128.28 (CH), 128.48 (CH), 139.64 (C), 146.90 (C), 175.48 (C); IR (KBr) 2957 (w), 2899 (w), 2885 (w), 2840 (m), 1742 (vs), 1702 (m), 1444 (m), 1339 (m), 1213 (s), 1176 (s), 962 (s) cm^{-1}; HREIMS *m/z* 264.1143 (calcd for $C_{18}H_{16}O_2$ 200.1150).

Allyl 4-Phenyl[4.4.1]propella-2,8-diene-11-carboxylate (20). A solution of crude **13a** (562 mg, 2 mmol) and allyl bromide (350 μL, 4 mmol) in 30 mL of dry CH_3CN was stirred in the presence of Cs_2CO_3 (424 mg, 3 mmol) under N_2 for 26 h. The reaction mixture was then treated with 40 mL of 1 M HCl and extracted with three 30-mL aliquots of CH_2Cl_2. The combined extracts were dried over $MgSO_4$ and concentrated to a yellow oil (607 mg), which was chromatographed on silica, eluting with a 50:1 mixture of hexane and ethyl acetate (400 mL), followed by a 25:1 mixture (300 mL). Allyl ester **20** was isolated as a colorless oil (565 mg) in 92% yield: ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 1.65 (dd, 1H, 14.3, 6.5), 1.88 (m, 1H, allylic H), 2.11 (s, 1H, $CHCO_2$), 2.31−2.47 (m, 2H, allylic CH_2), 2.60 (m, 1H, allylic H), 2.68 (dd, 1H, 14.2, 8.0), 3.50 (app td, 1H, 7.4, 2.5), 4.57 (d, 2H, 5.7, CO_2CH_2), 5.23 (app dd, 1H, 10.3, 1.3), 5.33 (app dd, 1H, 17.2, 1.5), 5.44−5.62 (m, 2H), 5.85 (br s, 2H), 5.96−6.04 (m, 1H), 7.14−7.32 (m, 5H, Ph H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 26.12 (C), 26.90 (C), 29.67 (CH_2), 30.88 (CH), 32.85 (CH_2), 34.78 (CH_2), 39.23 (CH), 64.83 (CH_2), 118.09 (CH_2), 123.76 (CH), 124.31 (CH), 126.03 (CH), 127.67 (CH), 127.78 (CH), 128.38 (CH), 129.98 (CH), 132.51 (CH), 145.60 (C), 170.76 (C); IR (film) 2881(s), 2831 (m), 1732 (vs), 1452 (m), 1153 (s) cm^{-1}; HREIMS *m/z* 306.1616 (calcd for $C_{21}H_{22}O_2$ 306.1620). Anal. Calcd for $C_{21}H_{22}O_2$: C, 82.31; H, 7.24. Found: C, 82.16; H, 7.40.

***syn*-11-Carboxy-3-phenyl-1,6-methano[10]annulene (22).** *syn*-11-((Allyloxy)carbonyl)-3-phenyl-1,6-methano[10]annulene (**21**) was prepared from **20** through the agency of DDQ via a procedure similar to that used to prepare **15**. The crude product was purified via silica chromatography, eluting with hexane/ethyl acetate to provide the desired compound contaminated with a small amount of the bridge epimer (8:1 based on integration of the ^{1}H-NMR spectrum): ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.65 (s, 1H, $CHCO_2$), 4.08 (br d, 2H, 5.5, CO_2CH_2), 4.99−5.12 (m, 2H, vinylic CH_2), 5.49−5.68 (m, 1H, vinylic CH), 6.98−7.03 (m, 2H, Ar H), 7.16−7.58 (m, 10H, Ar H); ^{1}H-NMR spectrum also contains signals for the minor isomer at 0.69 (s, 1H, $CHCO_2$), 4.14 (br d, 2H, 5.8, CO_2CH_2), 6.90 (m, 2H, Ar H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 48.91 (CH), 65.06 (CH_2), 115.31 (C), 115.62 (C), 118.40 (CH_2), 126.10 (CH), 126.25 (CH), 126.55 (CH), 127.13 (CH), 128.26 (CH), 128.46 (CH), 128.63 (CH), 129.69 (CH), 130.29 (CH), 131.82 (CH), 139.32 (C), 144.08 (C), 166.81 (C); IR (KBr) 1737 (s), 1229 (s), 1207 (vs), 1166 (s), 929 (s), 920 (m) cm^{-1}; HREIMS *m/z* 302.1300 (calcd for $C_{21}H_{18}O_2$ 302.1307). This material was carried on without further purification. $(Ph_3P)_4Pd$ (134 mg, 0.16 mmol) was added to a stirred solution of 351 mg (ca. 1.1 mmol) of this material and morpholine (1.01 mL, 11.6 mmol) in 30 mL of dry THF. After 75 min, the yellow solution was diluted with 100 mL of CH_2Cl_2 and washed three times with 50 mL of 1 M HCl. After drying over $MgSO_4$, the organic phase was concentrated on a rotary evaporator to a yellow solid that was chromatographed on silica, eluting with hexane/ethyl acetate mixtures. The desired material was obtained as a pale yellow solid (260 mg, 85%) that could be crystallized from ethyl acetate/hexane: mp 197−199 °C; ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.68 (s, 1H, $CHCO_2$), 7.06−7.16 (m, 2H, Ar H), 7.35−7.75 (m, 10H, Ar H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 48.59 (CH), 115.15 (C), 115.53 (C), 126.32 (CH), 126.47 (CH), 126.62 (CH), 127.14 (CH), 128.42 (CH), 128.76 (CH), 129.71 (CH), 130.40 (CH), 132.03 (CH), 132.18 (CH), 139.67 (C), 144.04 (C), 171.73 (C); IR (KBr) 3600−2300 (br), 2992 (m),

2959 (m), 2923 (m), 2900 (m), 2853 (m), 1703 (vs), 1282 (m), 1264 (m), 809 (s), 749 (s) cm^{-1}; HREIMS *m/z* 217.1017 (calcd for $C_{18}H_{14}O_2$ 217.1017).

Allyl 4-(3-((*tert*-Butyldimethylsilyl)oxy)phenyl)[4.4.1]propella-2,8-diene-11-carboxylate (23) was prepared from crude acid **13b** via a procedure similar to that used to prepare **20**. The crude product was chromatographed on silica, eluting with hexane/ethyl acetate (20:1). Two fractions were obtained; the first fraction contained the desired material **23**, a colorless oil (82%). The bisallylated product, allyl 4-(3-(allyloxy)phenyl)[4.4.1]propella-2,8-diene-11-carboxylate was isolated as a colorless oil from the second fraction (16%).

Allyl 4-(3-((*tert*-butyldimethylsilyl)oxy)phenyl)[4.4.1]propella-2,8-diene-11-carboxylate (**23**): ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.17 (s, 6H, $Si(CH_3)_2$), 0.97 (s, 6H, $C(CH_3)_3$), 1.65 (dd, 1H, 14.3, 6.1), 1.84−1.93 (m, 1H, allylic H), 2.10 (s, 1H, $CHCO_2$), 2.25−2.38 (m, 2H, allylic CH_2), 2.68 (dd, 1H, 14.3, 7.8), 3.39−3.46 (m, 1H), 4.55−4.59 (m, 2H, CO_2CH_2CH), 5.19−5.38 (m, 2H, vinylic CH_2), 5.38−5.55 (m, 2H), 5.86 (br s, 2H), 5.87−6.01 (m, 1H, $CO_2CH_2CHCH_2$), 6.63−6.68 (m, 2H, Ar H), 6.78 (br d, 1H, 7.6), 7.10 (m, 1H, Ar H); ^{13}C-NMR (67.5 MHz) δ 1.02 (CH_3), 18.13 (C), 25.64 (CH_3), 26.09 (C), 27.05 (C), 29.67 (CH_2), 30.73 (CH), 32.89 (CH_2), 34.54 (CH_2), 39.03 (CH), 64.81 (CH_2), 117.63 (CH), 118.09 (CH_2), 119.56 (CH), 120.73 (CH), 123.75 (CH), 124.34 (CH), 127.70 (CH), 129.17 (CH), 129.95 (CH), 132.51 (CH), 147.09 (C), 155.64 (C), 170.77 (C); IR (film) 2955 (s), 2929 (s), 2885 (s), 2831 (s), 1732 (vs), 1599 (s), 1583 (s), 1482 (s), 1278 (s), 1258 (s), 1157 (vs), 838 (s) cm^{-1}; HREIMS *m/z* 436.2426 (calcd for $C_{27}H_{36}O_3$ 436.2434).

Allyl 4-(3-(allyloxy)phenyl)[4.4.1]propella-2,8-diene-11-carboxylate:[1] H-NMR ($CDCl_3$, 200 MHz) δ 1.65 (dd 1H, 14.3, 6.3), 1.85−1.94 (m, 1H, allylic H), 2.10 (s, 1H, $CHCO_2$), 2.25−2.61 (m, 3H, allylic H), 2.68 (dd, 1H, 14.3, 7.9), 3.42−3.51 (m, 1H), 4.47−4.51 (m, 2H, $ArOCH_2CHCH_2$), 4.57 (br d, 2H, 5.8, CO_2CH_2), 5.20−5.43 (m, 4H, vinylic CH_2), 5.44−5.56 (m, 2H), 5.86 (br s, 2H), 5.89−6.11 (m, 2H, $CO_2CH_2CHCH_2$ and $ArOCH_2CHCH_2$), 6.73−6.80 (m, 2H, Ar H), 6.98−7.18 (m, 2H, Ar H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 25.87 (C), 26.80 (C), 29.54 (CH_2), 30.68 (CH), 32.72 (CH_2), 34.40 (CH_2), 39.07 (CH), 64.62 (CH_2), 68.34 (CH_2), 112.23 (CH), 113.80 (CH_2), 117.18 (CH), 117.88 (CH), 120.11 (CH), 123.54 (CH), 124.22 (CH), 127.61 (CH), 129.15 (CH), 129.78 (CH), 132.36 (CH), 133.18 (CH), 147.01 (C), 158.54 (C), 170.49 (C); IR (film) 3026 (m), 2923 (m), 2882 (m), 2831 (m), 1731 (vs), 1597 (s), 1583 (s), 1485 (s), 1445 (s), 1422 (s), 1303 (m), 1159 (vs) cm^{-1}; HREIMS *m/z* 362.1846 (calcd for $C_{24}H_{26}O_3$ 362.1882).

***syn*-11-((Allyloxy)carbonyl)-3-(3-((*tert*-butyldimethylsilyl)oxy)-phenyl)-1,6-methano[10]annulene (24)** was prepared from **23** through the agency of DDQ via a proceudre similar to that used to prepare **15**. The crude product was chromatographed on silica, eluting with 1−2% ethyl acetate in hexane to provide **24** as a yellow oil (62%): ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.23 (s, 6H, $Si(CH_3)_2$), 0.71 (s, 1H, $CHCO_2$), 1.01 (s, 9H, $C(CH_3)_3$), 4.15 (m, 2H, CO_2CH_2), 5.08−5.21 (m, 2H, vinylic CH_2), 5.57−5.73 (m, 1H, vinylic H), 6.80−6.85 (m, 1H, Ar H), 7.03−7.30 (m, 6H, Ar H), 7.44−7.60 (m, 4H, Ar H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 0.75 (CH_3), 18.17 (C), 25.68 (CH_3), 48.87 (CH), 64.99 (CH_2), 115.21 (C), 115.57 (C), 118.34 (CH_2), 118.69 (CH), 120.38 (CH), 121.77 (CH), 126.02 (CH), 126.21 (CH), 126.45 (CH), 128.22 (CH), 129.28 (CH), 129.65 (CH), 130.23 (CH), 131.787 (CH), 139.02 (C), 145.59 (C), 155.65 (C), 166.74 (C); IR (film) 2929 (s), 2857 (s), 1741 (vs), 1596 (s), 1577 (s), 1483 (s), 1472 (s), 1289 (s), 1253 (s), 1192 (s), 1182 (s) cm^{-1}; HREIMS *m/z* 432.2121 (calcd for $C_{26}H_{32}O_3Si$ 432.2121). Anal. Calcd for $C_{27}H_{36}O_3Si$: C, 74.24; H, 8.31. Found: C, 74.52; H, 8.63.

***syn*-11-((Allyloxy)carbonyl)-3-(3-hydroxyphenyl)-1,6-methano[10]-annulene (25).** Hydrobromic acid (82 μL, 48%, 0.72 mmol) was added to a solution of **24** (1.57 g, 3.6 mmol) in 50 mL of DMF in the presence of KF (422 mg, 7.3 mmol).[20] The resulting mixture was stirred for 45 h under N_2 before treatment with 60 mL of 1 M HCl. The aqueous mixture was extracted three times with 40 mL of CH_2Cl_2, and the combined extracts were dried over $MgSO_4$. After the solvents had been removed, the residue was chromatographed on silica, eluting with 3:1 hexane/ethyl acetate, providing the desired product as a slightly yellow oil (1.109 g, 97%): ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.70 (s, 1H, $CHCO_2$), 3.00 (br s, 1H), 4.13 (br d, 5.7, CO_2CH_2), 5.03−5.15 (m, 2H, vinylic CH_2), 5.51−5.67 (m, 1H, vinylic CH), 6.86 (br d, 1H, 7.6), 6.98−7.52 (m, 10H, Ar H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 48.85 (CH), 65.26 (CH_2), 114.34 (CH), 115.02 (C), 115.48 (C), 115.69 (CH), 118.60 (CH_2), 120.58 (CH), 125.86 (CH), 126.19 (CH), 126.42 (2CH), 128.23 (CH), 129.54 (2CH), 130.20 (CH), 131.34 (CH), 138.93 (C), 145.38 (C), 156.09 (C), 167.67 (C); IR (film) 3600−2600 (br), 3022 (s), 2984 (s), 2948 (s), 1732 (s), 1716 (s), 1595 (s), 1583 (s), 1449 (m), 1306 (m), 1229 (m), 1222 (m) cm^{-1}; HREIMS *m/z* 318.1256 (calcd for $C_{21}H_{18}O_3$ 318.1256).

***syn*-11-((Allyloxy)carbonyl)-3-(3-(propyloxy)phenyl)-1,6-methano-[10]annulene (26).** Iodopropane (133 μL, 1.41 mmol) was added to a solution of **25** (226 mg, 0.71 mmol) in 15 mL of dry CH_3CN in the presence of Cs_2CO_3 (347 mg, 1.06 mmol) under N_2. The reaction mixture was stirred at room temperature for 18.5 h before 30 mL of 1 M HCl was added. The resulting aqueous mixture was extracted three times with 30 mL of CH_2Cl_2, and the extracts were combined, dried over $MgSO_4$, and concentrated. The yellow residue so obtained was chromatographed on silica, eluting with a 10:1 mixture of hexane and ethyl acetate to afford 226 mg of **26**, a yellow oil (88%): ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.71 (s, 1H, $CHCO_2$), 1.05 (t, 3H, 7.4, $OCH_2CH_2CH_3$), 1.82 (sextet, 2H, 7.2, $OCH_2CH_2CH_3$), 3.96 (t, 2H, 6.5, $OCH_2CH_2CH_3$), 4.15 (d, 2H, 5.8, CO_2CH_2), 5.07−5.23 (m, 2H, vinylic CH_2), 5.56−5.76 (m, 1H, vinylic CH), 6.89 (dd, 1H, 8.1, 2.4), 6.98−7.19 (m, 4H, Ar H), 7.26−7.32 (m, 2H, Ar H), 7.46−7.58 (m, 4H, Ar H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 10.54 (CH_3), 22.59 (CH_2), 48.85 (CH), 65.00 (CH_2), 69.44 (CH_2), 113.12 (CH), 114.98 (CH), 115.19 (C), 115.62 (C), 118.33 (CH_2), 120.83 (CH), 126.02 (CH), 126.20 (CH), 126.45 (2 CH), 126.51 (CH), 128.19 (CH), 129.31 (CH), 129.64 (CH), 130.23 (CH), 131.78 (CH), 139.14 (C), 145.47 (C), 159.19 (C), 166.73 (C); IR (KBr) 3040 (m), 3023 (m), 2964 (s), 2936 (s), 2876 (s), 1739 (vs), 1604 (s), 1596 (s), 1577 (s), 1487 (m), 1473 (m), 1450 (m), 1316 (m), 1305 (m), 1288 (s), 1222 (s), 1190 (s) cm^{-1}; HREIMS *m/z* 360.1700 (calcd for $C_{24}H_{24}O_3$ 360.1725). Anal. Calcd for $C_{24}H_{24}O_3$: C, 74.96; H, 7.45. Found: C, 74.47; H, 7.72.

***syn*-11-Carboxy-3-(3-(propyloxy)phenyl-1,6-methano[10]-annulene (27)** was prepared from **26** in a procedure similar to that used to prepare **22**. The crude product was chromatographed on a silica column, eluting with 2:1 hexane/ethyl acetate, providing the desired compound as a slightly yellow solid in 79% yield. Some of this material was crystallized from hot ethyl acetate, providing yellow prisms: mp 185−186 °C dec; ^{1}H-NMR ($CDCl_3$, 200 MHz) δ 0.63 (s, 1H, $CHCO_2$), 1.08 (t, 3H, 7.4, $OCH_2CH_2CH_3$), 1.86 (sextet, 2H, 6.9, $OCH_2CH_2CH_3$), 3.98 (t, 2H, 6.5, $OCH_2CH_2CH_3$), 6.90 (br d, 1H, 9.2), 7.00−7.06 (m, 5H, Ar H), 7.28 (app t, 1H, 8.1, H16), 7.40−7.45 (m, 4H, Ar H); ^{13}C-NMR ($CDCl_3$, 67.5 MHz) δ 10.63 (CH_3), 22.67 (CH_2), 48.59 (CH), 69.52 (CH_2), 113.42 (CH), 114.96 (CH), 115.14 (C), 115.56 (C), 121.04 (CH), 126.24 (CH), 126.33 (2 CH), 126.63 (CH), 128.00 (CH), 129.35 (CH), 129.64 (CH), 130.36 (CH), 139.68 (C), 145.43 (C), 159.18 (C), 173.03 (C); IR (KBr) 3500−2300 (br), 1698 (vs), 1594 (s), 1491 (m), 1474 (m), 1433 (m), 1420 (m), 1415 (m), 1323 (m), 1281 (s), 1270 (s), 1256 (s), 1219 (m), 1193 (s) cm^{-1}; HREIMS *m/z* 320.1408 (calcd for $C_{21}H_{20}O_3$ 320.1412).

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Supplementary Material Available: Tables of crystallographic data for **12**, **13a**, and **19** (24 pages); listings of structure factors (16 pages). This material is contained in many libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be order from the ACS; see any current masthead page for ordering information.