90 °C (0.8 torr); IR (neat) 2220, 1725 cm^{-1}. **30c** (65 %): bp 70 °C (0.4 torr); IR (CCl_4) 2215, 1720 cm^{-1}. **30d** (70 %): bp 100 °C (2.5 torr); IR (CCl_4) 2220, 1715, 1220–1210 cm^{-1}. **30e** (80%): bp 140 °C (0.2 torr); IR (CCl_4) 2220, 1720 cm^{-1}. **30f** (65 %): bp 70 °C (0.2 torr); mass spectrum, m/e 177 (M^+, 2) (HRMS calcd for $C_{11}H_{15}NO$ 177.1153, found 177.114), 162 (7), 108 (5), 69 (100), 57 (23), 43 (21); IR (CCl_4) 2215, 1720 cm^{-1}. **30g + 31**: bp 75 °C (2 torr). **30g** (55 %): IR (CCl_4) 2220, 1720, 1250 cm^{-1}. **31** (*Z* isomer) (6 %): ^1H NMR (CCl_4) δ 5.60 (1 H, s (br)), 1.17 (3, d, J = 7.0 Hz), 0.18 (9, s). **31** (E isomer) (3 %): ^1H NMR (CCl_4) δ 5.75 (1 H, s), 1.10 (3, d, J = 7.0 Hz), 0.18 (9, s); IR (CCl_4) 2220, 1720, 1600, 1250 cm^{-1}. (See Table VII for ^1H NMR spectral data for **30a–g**.)

Preparation of 33 and 34. The procedure is repeated with 3.8 g (20 mmol) of titanium tetrachloride and 11.4 g (50 mmol) of **32**, **33** and **34**: bp 90 °C (0.8 torr). **33** (40%): ^1H NMR (CCl_4) δ 7.40–6.70 (2 H, part AB of ABX_3pattern), 1.95 (3, d, J = 6.0 Hz), 1.65 (6, s), 0.13 (9, s); IR (CCl_4) 2170, 1700, 1630, 1250 cm^{-1}. **34a** (10 %): ^1H NMR (CCl_4) δ 5.47 (1 H, d, J = 3.0 Hz), 1.57 (6, s), 1.14 (3, d, J = 7.0 Hz), 0.17 (9, s); mass spectrum, m/e 233 ($M^+ - H_2O$, 1) (HRMS calcd for $C_{13}H_{19}NOSi$ 233.1235, found 233.121), 218 (9), 205 (7), 190 (10), 138 (16), 124 (14), 123 (100), 106 (9), 97 (8), 73 (33), 69 (27), 43 (10), 41 (9); IR (CCl_4) 3620, 3560–3200, 2240, 1250 cm^{-1}. **34b** (10%): ^1H NMR (CCl_4) δ 5.64 (1 H, d, J = 3.0 Hz), 1.69 (6, s), 1.37 (3, d, J = 7.0 Hz), 0.37 (9, s), 0.17 (9, s); mass spectrum, m/e 233 ($M^+ - OSiMe_3$, 1), 218 ($M^+ - OSiMe_3 - CH_3$, 5) (HRMS calcd for $C_{12}H_{16}NOSi$ 21.1001, found 218.099), 205 (3), 190 (11), 163 (4), 138 (11), 136 (10), 124 (14), 123 (100), 106 (7), 97 (11), 73 (24), 69 (32), 43 (7), 41 (8); IR (CCl_4) 2240, 2185, 1680, 1250 cm^{-1}.

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Synthesis of Potential Phenolic Metabolites of Benzo[*b*]fluoranthene[1,2]

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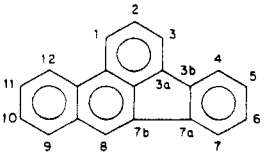
The syntheses of the 12 isomeric hydroxybenzo[*b*]fluoranthenes (hydroxy-BbF, 1–12) are described. 1-Hydroxy-BbF was prepared by treatment of 1-oxo-1,2,3,3a-tetrahydro-BbF (**13**) with Pd/C. 2-Hydroxy-BbF was synthesized by reduction of **13** with $NaBH_4$, followed by dehydration, epoxidation, and treatment with Pd/C. 3-Hydroxy-BbF was obtained by reduction of **13** with Zn(Hg) followed by oxidation with Triton-B, dehydration, epoxidation, and aromatization. 4-Hydroxy-BbF and 7-hydroxy-BbF were prepared by reaction of acephenanthrylene with 1-acetoxybutadiene, aromatization, hydrolysis, and separation by HPLC. 5-Hydroxy-BbF was synthesized by reaction of *o*-bromobenzaldehyde with 3-methoxyfluorene, followed by cyclization with KOH and quinoline, hydrolysis, and purification by HPLC. 6-Hydroxy-BbF was obtained by regiospecific cyclization of 3-methoxy-11*H*-benzo[*b*]fluorene-11-propionic acid (**33**), followed by reduction, dehydration, aromatization, and hydrolysis. 8-Hydroxy-BbF was synthesized by dehydration of 7b,8-dihydro-7b,8-dihydroxy-BbF (**39**). 9-Hydroxy-BbF and 12-hydroxy-BbF were prepared by treatment of the corresponding oxotetrahydro-BbFs with Pd/C. 10-Hydroxy-BbF and 11-hydroxy-BbF were synthesized by reaction of fluorene with the appropriate bromomethoxybenzaldehyde followed by cyclization with hydrolysis.

Polynuclear aromatic hydrocarbons (PAH) are metabolically converted to epoxides, dihydrodiols, phenols, tetrols, quinones, and a variety of related metabolites and conjugates. Some of these metabolites such as dihydrodiol epoxides and phenolic dihydrodiol epoxides are involved in the DNA binding properties and carcinogenic activities of PAH.[3] Thus, an understanding of PAH metabolism is important for determining the mechanisms by which they cause cancer. Benzo[*b*]fluoranthene (BbF) is a widely distributed environmental carcinogen.[4] It is metabolically converted in vitro and in vivo to dihydro diols, phenols, and other metabolites.[5,6] The dihydro diols have been identified by comparison to synthetic samples.[5,7] There are 12 possible phenols which can be formed from BbF. In this report, we describe the synthesis of these potential metabolites, **1–12**.



BbF

Results and Discussion

The starting material for the syntheses of 1-hydroxy-BbF (**1**), 2-hydroxy-BbF (**2**), and 3-hydroxy-BbF (**3**) was 1-oxo-1,2,3,3a-tetrahydro-BbF (**13**), which we had previously prepared by regiospecific cyclization of 11*H*-benzo[*b*]fluorene-11-propionic acid chloride.[7] Treatment of **13** with Pd/C yielded **1**. Reduction of **13** with $NaBH_4$ followed by dehydration and epoxidation with *m*-chloroperbenzoic acid gave **14**, which was treated with Pd/C to give **2**. 1-Hydroxy-BbF was not observed in this reaction. As an alternate approach to **2**, we investigated the reaction of 1,2-(dibenzoyloxy)-1,2,3,3a-tetrahydro-BbF with *p*-toluenesulfonic acid (PTSA), followed by hydrolysis and

(1) A Study of Chemical Carcinogenesis 93.
(2) Supported by Contract N01-CP-15747 from the National Cancer Institute.
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(7) Amin, S.; Hussain, N.; Brielmann, H.; Hecht, S. S. *J. Org. Chem.* **1984**, *49*, 1091–1095.

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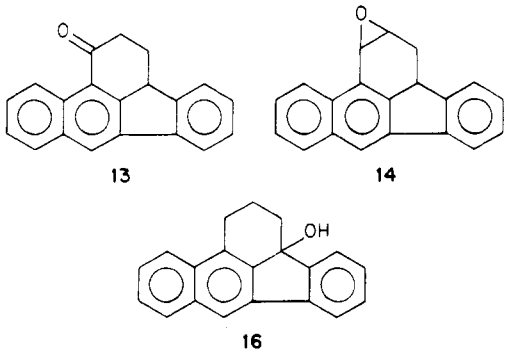
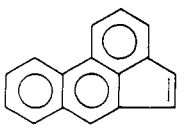


13 14 16

aromatization. This approach was not successful although it has been used in other PAH systems.[8] For the synthesis of 3-hydroxy-BbF (**3**), **13** was reduced with Zn(Hg) to give 1,2,3,3a-tetrahydro-BbF (**15**). Oxidation with triton-B yielded 3a-hydroxy-1,2,3,3a-tetrahydro-BbF (**16**), which was dehydrated to 1,2-dihydro-BbF (**17**). Treatment of **17** with *m*-chloroperbenzoic acid followed by aromatization with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) gave **3**.

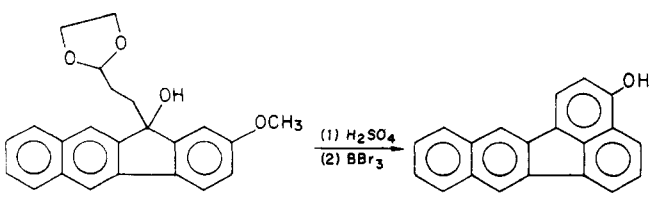
The syntheses of 4-hydroxy-BbF (**4**) and 7-hydroxy-BbF (**7**) began with acephenanthrylene (**18**).[9] Reaction of **18** with 1-acetoxybutadiene followed by aromatization with DDQ and hydrolysis gave a mixture of **4** (70%) and **7** (30%), which was separated by HPLC. They were iden-



18

tified by NMR, as shown in Figure 1. In the spectrum of **4**, the 3-proton was observed at 8.19 ppm and the 8-proton at 8.24 ppm, whereas in the spectrum of **7** the 3-proton was observed at 8.05 ppm and the 8-proton at 8.43 ppm. These results are consistent with deshielding of the 3- and 8-protons by the neighboring 4-hydroxy and 7-hydroxy groups, respectively.

The synthesis of 5-hydroxy-BbF (**5**) is outlined in Scheme I. Reaction of *o*-bromobenzaldehyde (**19**) with 3-methoxyfluorene (**20**) yielded the isomeric condensation products **21**. Cyclization and hydrolysis gave a mixture of **5** and 2-hydroxy-BbF (**2**) which was separated by HPLC. The methoxy group had no apparent directing effect in this base-catalyzed cyclization. As an alternative approach to **5**, we investigated the acid-catalyzed cyclization of **23**, prepared from 2-methoxy-11*H*-benzo[*b*]fluoren-11-one (**22**). However, this reaction gave exclusively 3-methoxybenzo[*k*]fluoranthene (**24**) and, upon treatment with BBr_3, **25**. The direction of cyclization was opposite to that observed in the preparation of **13**.[7] This clearly resulted from the strong directing effect of the *o*-methoxy group.



23 25

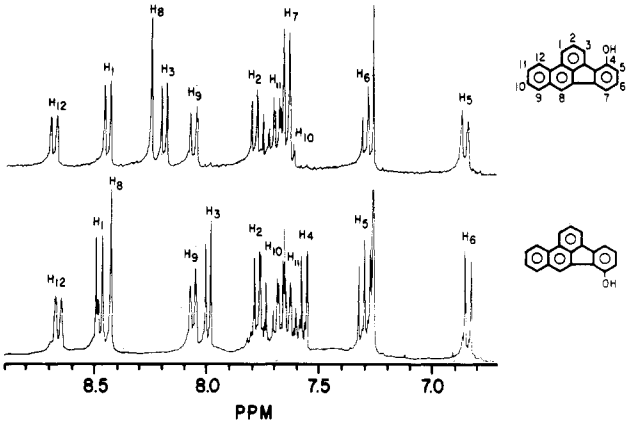
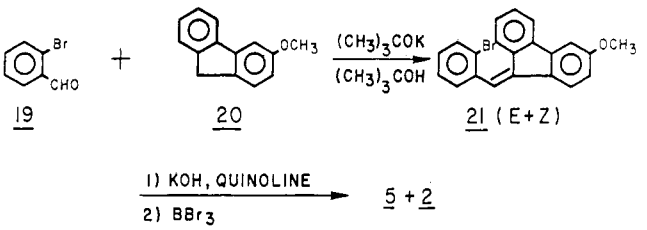
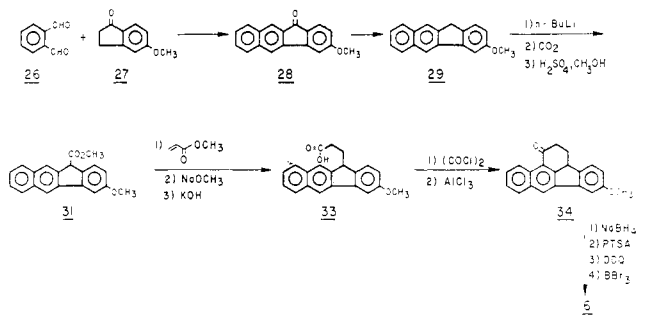


Figure 1. NMR spectra of 4-hydroxy-BbF and 7-hydroxy-BbF.

Scheme I. Synthesis of 5-Hydroxy-BbF (5)

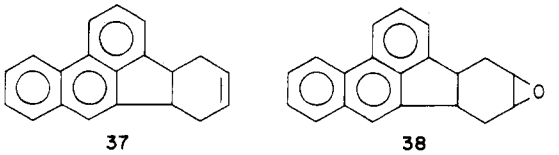


Scheme II. Synthesis of 6-Hydroxy-BbF (6)



The synthesis of 6-hydroxy-BbF (**6**) is summarized in Scheme II. The key step was the regiospecific cyclization of **33** to give the appropriate ketone **34** rather than the precursor to a benzo[*k*]fluoranthene as in the cyclization of **23**. In this case, the cyclization proceeded toward the α-position of the naphthalene ring, as in the preparation of **13**, because of the meta orientation of the methoxy group.

Compounds **5** and **6** were also prepared from acephenanthrylene (**18**). Reaction of **18** with butadiene gave 3b,4,7,7a-tetrahydro-BbF (**37**), which was converted to the corresponding epoxide **38**. Aromatization gave a mixture of **5** (50%) and **6** (50%), which was separated by HPLC. However, the yields in this route were inferior to those described above.



37 38

8-Hydroxy-BbF (**8**) was prepared by PTSA-catalyzed dehydration of 7b,8-dihydro-7b,8-dihydroxy-BbF (**39**).[10]

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Scheme III. Syntheses of 10-Hydroxy-BbF (10) and 11-Hydroxy-BbF (11)

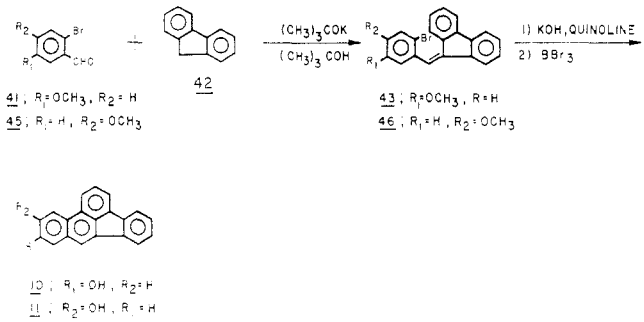

Table I. Capillary GC[a] and HPLC Retention Times of Hydroxybenzo[*b*]fluoranthenes

compd	GC t_r,[b] min	HPLC t_r,[c] min	compd	GC t_r,[b] min	HPLC t_r,[c] min
1	28.9	31.30	7	28.4	27.90
2	29.1	28.10	8	26.4	27.80
3	30.3	28.00	9	32.5	31.30
4	30.5	35.40	10	33.2	30.40
5	32.2	31.30	11	31.5	32.80
6	32.2	28.00	12	29.1	37.40

[a] Hydroxybenzo[*b*]fluoranthenes were analyzed as their trimethylsilyl derivatives. [b] A 0.2-μm SE-54 25-m fused silica column was programmed from 200–250 °C at 2 °C/min. [c] A 4.6 mm × 250 mm Vydac 201 TP104 10-μm column eluted from 70% CH_3OH in H_2O to 100% CH_3OH in 90 min at 1 mL/min.

9-Hydroxy-BbF (**9**) was synthesized by treatment of 9-oxo-9,10,11,12-tetrahydro-BbF (**40**)[11] with Pd/C. The syntheses of 10-hydroxy-BbF (**10**) and 11-hydroxy-BbF (**11**) are outlined in Scheme III. These were accomplished by employing the base-catalyzed condensation procedure for preparation of BbF derivatives.[12] Since fluorene was the starting material, no isomeric mixtures were produced as in the synthesis of **5**. Preparation of 12-hydroxy-BbF (**12**) was accomplished by treatment of 12-oxo-9,10,11,12-tetrahydro-BbF (**48**) with Pd/C, as in the syntheses of **1** and **9**.

Phenolic metabolites of PAH can be identified by their characteristic UV spectra and by their chromatographic retention times. Figure 2 illustrates the UV spectra of **1–12**.[13] The HPLC and capillary GC retention times of compounds **1–12** are summarized in Table I. Using this data base, the major phenolic metabolites of BbF formed by 9000 × *g* supernatant from livers of rats pretreated with Aroclor 1254 have been identified as 4-, 5-, and 6-hydroxy-BbF. Two minor metabolites were identified as 11- and 12-hydroxy-BbF.[14]

Experimental Section

Infrared spectra were run on a Perkin-Elmer Model 267 grating infrared spectrophotometer. 90-MHz NMR spectra were determined with a Jeol Model FX90Q spectrometer with $CDCl_3$ as solvent and are reported as parts per million downfield from Me_4Si as an internal reference. 300-MHz NMR spectra were obtained on the NTC wide bore spectrometer at Rockefeller University. UV spectra were determined in CH_3OH with a Cary Model 118 instrument. HPLC was carried out with a Waters Associates Model ALC/GPC-204 high-speed liquid chromatograph equipped with a Model 660 solvent programmer, a Model LC-25 UV–vis detector and a 4.6 mm (i.d.) × 250 mm Vydac 201 TP104 10 μm column eluted from 70% CH_3OH in H_2O to 100% CH_3OH in 90 min at 1 mL/min. Capillary GC was carried out with a Hewlett-Packard Model 5710A gas chromatograph equipped with a Model 18740B capillary control unit, a Model 3380A calculating integrator, a 0.25-μm SE-54 25-m fused silica column, and a flame ionization detector. The oven temperature was programmed from 200–250 °C at 2 °C/min. Helium was used as carrier gas with a flow rate of 1 mL/min. MS were run with a Hewlett-Packard Model 5982A dual source instrument using a membrane separator. Microanalyses were performed by Galbraith Laboratories.

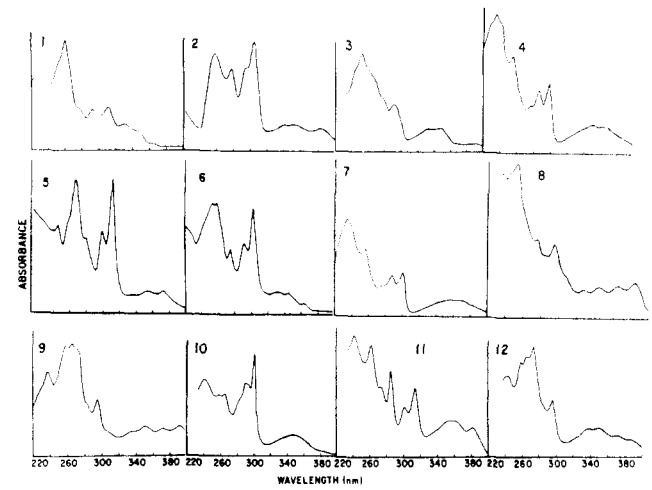

Figure 2. UV spectra of hydroxy-substituted BbF at positions 1–12. See ref 13.

1-Hydroxy-BbF (1). A solution of ketone **13** (0.27 g, 1 mmol) and Pd/C (0.1 g) in 50 mL of 1-methylnaphthalene was heated at reflux for 36 h. The catalyst was removed by filtration through a bed of Celite and washed with benzene. The solvent was removed under reduced pressure via distillation, affording 200 mg of crude **1**. The crude product was purified by chromatography on silica gel, with elution by CH_2Cl_2/hexane (50:50) to afford 1-hydroxy-BbF (**1**) (160 mg, 59.7%) as a light yellow solid: mp 235–236 °C; NMR δ 7.2 (d, 1 H, $J_{2,3}$ = 8.0 Hz), 7.25–8.1 (m, 8 H), 8.2 (s, 1 H), 9.6 (d, 1 H); MS, *m/e* (relative intensity) 268 (M^+, 100), 239 (24.8). Anal. Calcd for $C_{20}H_{12}O$: C, 89.52; H, 4.51. Found: C, 89.35; H, 4.60.

1,2-Epoxy-1,2,3,3a-tetrahydro-BbF (14). A solution of 3,3a-dihydro-BbF[7] (0.12 g, 0.5 mmol) and *m*-chloroperbenzoic acid (0.86 g, 5 mmol) in THF (50 mL) was stirred for 4 h under N_2. The product was diluted with 100 mL of ether, washed with ice-cold 5% aqueous NaOH (3 × 15 mL) and H_2O, and dried with anhydrous K_2CO_3. Evaporation of the solvent at room temperature gave crude **14**. The pure epoxide was obtained by chromatography on silica gel with elution by CH_2Cl_2/hexane (50:50), affording **14** (55 mg, 41%) as a solid: mp 118–120 °C; NMR δ 3.0–3.25 (m, 1 H), 3.9–4.20 (m, 3 H), 4.65 (d, 1 H), 7.2–8.3 (m, 9 H); MS, *m/e* (relative intensity) 270 (M^+, 100), 254 (54).

2-Hydroxy-BbF (2). The conversion of **14** (0.13 g, 0.5 mmol) to the corresponding phenol **2** was carried out as described for preparation of **1**. The crude product was purified by chromatography on silica gel with elution by CH_2Cl_2/hexane (50:50) to afford 2-hydroxy-BbF (**2**) (64 mg, 48%): mp 221–222 °C; NMR δ 7.25–8.15 (m, 10 H), 8.5–8.7 (m, 1 H); MS, *m/e* (relative intensity) 268 (M^+, 100), 239 (15). Anal. Calcd for $C_{20}H_{12}O$: C, 89.52; H, 4.51. Found: C, 89.32; H, 4.70.

1,2,3,3a-Tetrahydro-BbF (15). A mixture of Zn(Hg) (2.6 g, 10 mmol), 1.65 mL of concentrated HCl, 10 mL of acetic acid, 10 mL of toluene, and 1.35 g (5 mmol) of **13**[7] was heated at reflux for 4 h. The reaction mixture was filtered, and the Zn was washed with Et_2O. The organic layer was washed with H_2O, dried ($MgSO_4$), and evaporated to give crude **15**. Purification via silica gel chromatography using hexane/CH_2Cl_2 (80:20) as the eluant gave pure **15** (0.7 g, 55%): mp 127–128 °C; NMR δ 1.2–1.5 (m,

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(13) In a previous report on the identification of metabolites of BbF,[5] the legends of Figures 5a and 5b were inadvertently switched. Thus, Figure 5a represents the UV spectra of 4- or 7-hydroxy-BbF and Figure 5b the spectra of 5- or 6-hydroxy-BbF.
(14) Amin, S.; Huie, K.; Hussain, N.; Balanikas, G.; Geddie, J. E.; LaVoie, E. J.; Hecht, S. S. *Polynucl. Aromat. Hydrocarbons: Proc. Int. Conf. 9th*, in press.

1 H), 2.1–2.7 (m, 4 H), 3.0–3.4 (m, 1 H), 3.80 (dd, 1 H), 7.2–7.6 (m, 5 H), 7.8–8.0 (m, 4 H); MS, *m/e* (relative intensity) 256 (M^+, 100), 228 (70). Anal. Calcd for $C_{20}H_{16}$: C, 93.70; H, 6.29. Found: C, 93.52; H, 6.14.

1,2-Dihydro-BbF (17). Benzyltrimethylammonium hydroxide (0.5 mL) was added to a solution of **15** (0.25 g, 1 mmol) in pyridine. A dark red color developed immediately, and the reaction mixture was stirred further for 12 h and then poured into H_2O and extracted with CH_2Cl_2 (3 × 100 mL). The organic extracts were washed with $NaHSO_3$ solution (20%, 3 × 50 mL) and H_2O, dried ($MgSO_4$), and concentrated to give 0.15 g (60%) of **16**, which was used directly in the next step: MS, *m/e* (relative intensity) 272 (M^+, 30), 254 (58).

A solution of the above alcohol and PTSA (5 mg) in benzene (50 mL) was heated at 50 °C for 1 h. Conventional workup followed by chromatography on silica gel eluted with hexane/CH_2Cl_2 (90:10) afforded **17** (80 mg, 51%) as a solid: mp 152–153 °C; NMR δ 2.8–3.1 (m, 2 H), 3.2–3.5 (m, 2 H), 6.55 (t, 1 H), 7.2–7.55 (m, 4 H), 7.6–8.1 (m, 5 H); MS, *m/e* (relative intensity) 254 (M^+, 100). Anal. Calcd for $C_{20}H_{14}$: C, 94.45; H, 5.55. Found: C, 94.65; H, 5.49.

3-Hydroxy-BbF (3). A solution of **17** (0.12 g, 0.5 mmol) and *m*-chloroperbenzoic acid (0.17 g, 1 mmol) in THF (10 mL) was stirred at 20 °C for 3 h. Conventional workup followed by chromatography on silica gel eluted with hexane/CH_2Cl_2 (70:30) afforded an epoxide which was sufficiently pure to be used in the subsequent step.

A solution of the above epoxide and DDQ (0.1 g, 0.4 mmol) in 50 mL of benzene was heated at reflux for 1 h. The reaction mixture was worked up in the usual manner. The crude product was purified by chromatography on silica gel with elution by CH_2Cl_2/hexane (50:50) to afford 3-hydroxy-BbF (**3**) (46 mg, 35%): mp 248–249 °C; NMR δ 7.3–7.8 (m, 6 H), 7.9–8.2 (m, 3 H), 8.25 (s, 1 H), 8.55 (dd, 1 H); MS, *m/e* (relative intensity) 268 (M^+, 100), 239 (35). Anal. Calcd for $C_{20}H_{12}O$: C, 89.52; H, 4.51. Found: C, 89.27; H, 4.58.

4- and 7-Hydroxy-BbF (4 and 7). Acephenanthrylene (**18**)[9] (0.2 g, 0.01 mol), 1-acetoxybutadiene (1 mL), and hydroquinone (10 mg) were heated in a sealed tube at 160 °C for 30 h. The reaction mixture was dissolved in ether (150 mL) and washed with 5% aqueous NaOH (2 × 150 mL) and H_2O, dried ($MgSO_4$), and concentrated to afford 150 mg of crude product as a yellow oil. The crude compound was purified by chromatography on silica gel with elution by hexane to give unreacted acephenanthrylene (10 mg). Further elution by hexane/CH_2Cl_2 (70:30) afforded 100 mg of a mixture of 4- and 7-acetoxy-3b,4,7,7a-tetrahydro-BbF: MS, *m/e* (relative intensity) 314 (M^+, 37.1), 254 (78.3).

The above compounds were dissolved in benzene (30 mL), and 90 mg (0.4 mmol) of DDQ was added. The reaction mixture was heated at reflux for 30 min, in an atmosphere of N_2. The residue obtained after removal of the solvent was purified by chromatography on silica gel. Elution with hexane/CH_2Cl_2 (70:30) afforded a mixture of 4- and 7-acetoxy-BbF as an oil (62 mg, 20%): NMR δ 2.5 (s, 2.25 H, CH_3), 2.55 (s, 0.75 H, CH_3), 7.1–8.2 (m, 9 H), 8.3–8.7 (m, 2 H); MS, *m/e* (relative intensity) 310 (M^+, 21.2), 268 (100), 239 (60.6).

To a solution of the above compounds in CH_3OH (5 mL) was added NaOMe (0.1 g, 2.0 mmol) in MeOH (100 mL), and the resulting mixture was stirred at 20 °C for 1 h. EtOAc (10 mL) was added, and the organic phase was washed with HCl (2 N, 10 mL), H_2O (20 mL), dried ($MgSO_4$), and concentrated to give a mixture of **4** and **7**, which was separated by HPLC: 300-MHz NMR of **4**: δ 6.85 (d, 1 H, H_5, $J_{5,6}$ = 8.0 Hz), 7.28 (t, 1 H, H_6, $J_{5,6}$ = $J_{6,7}$ = 8 Hz), 7.6–7.8 (m, 4 H), 8.06 (d, 1 H, H_9, $J_{9,10}$ = 8 Hz), 8.19 (d, 1 H, H_3, $J_{2,3}$ = 7.0 Hz), 8.24 (s, 1 H, H_8), 8.44 (d, 1 H, H_1, $J_{1,2}$ = 8.0 Hz), 8.68 (d, 1 H, H_{12}, $J_{11,12}$ = 7.4 Hz); MS, *m/e* (relative intensity) 268 (M^+, 100), 239 (15). 300-MHz NMR of **7**: δ 6.84 (d, 1 H, H_6, $J_{5,6}$ = 8.0 Hz), 7.3 (t, 1 H, H_5, $J_{4,5}$ = $J_{5,6}$ = 8 Hz), 7.5–7.8 (m, 4 H), 8.0 (d, 1 H, H_9, $J_{9,10}$ = 8 Hz), 8.05 (d, 1 H, H_3, $J_{2,3}$ = 7.0 Hz), 8.43 (s, 1 H, H_8), 8.48 (d, 1 H, H_1, $J_{1,2}$ = 8 Hz), 8.65 (d, 1 H, H_{12}, $J_{11,12}$ = 8.0 Hz); MS, *m/e* (relative intensity) 268 (M^+, 100), 239 (14.9). Anal. Calcd for **4**: C, 89.52; H, 4.51. Found: C, 89.29; H, 4.42. Anal. Calcd for **7**: C, 89.52; H, 4.51. Found: C, 89.26; H, 4.67.

9-(*o*-Bromobenzylidene)-3-methoxyfluorene (21). The reaction of 3-methoxyfluorene (**20**, 1.29 g, 6 mmol),[15] *o*-bromobenzaldehyde (**19**, 1.1 g, 6 mmol), and *t*-BuOK (0.73 g, 6 mmol) in *t*-BuOH (50 mL) was effected as described for the synthesis of **44**. The crude product was purified by chromatography on silica gel with elution by CH_2Cl_2/hexane (30:70), affording **21** (*E* + *Z* isomers), as a viscous liquid: NMR δ 3.85 (s, 1.8 H, OCH_3), 3.92 (s, 1.2 H, OCH_3), 6.55 (dd, 1 H, $J_{1,2}$ = 10 Hz, $J_{2,4}$ = 2.5 Hz), 6.8–7.85 (m, 11 H); MS, *m/e* (relative intensity) 364 (M^+, 96.2), 362 (100), 283 (21.5). Anal. Calcd for $C_{21}H_{15}BrO$: C, 69.43; H, 4.16; Br, 21.96. Found: C, 69.45; H, 4.14; Br, 21.66.

5-Hydroxy-BbF (5). The reaction of **21** (0.18 g, 0.5 mmol) and KOH (112 mg, 2 mmol) in quinoline was effected as described for **44**. The crude product was purified by chromatography on silica gel. Elution with hexane/CH_2Cl_2 (70:30) gave a mixture of 2- and 5-methoxy-BbF, which was used directly in the next step: MS, *m/e* (relative intensity) 282 (M^+, 100).

A solution of the above methoxy-BbF and BBr_3 (140 mg, 0.5 mmol) in CH_2Cl_2 (100 mL) was stirred at room temperature for 12 h. After the mixture had cooled, the dark solution was diluted with 100 mL of H_2O and neutralized with aqueous $NaHCO_3$. The organic layer was collected, washed with H_2O, dried ($MgSO_4$), and concentrated. Chromatography on silica gel eluted with CH_2Cl_2/hexane (50:50) afforded 2- and 5-hydroxy-BbF, which were separated by HPLC. **5**: NMR δ 6.85–7.0 (dd, 1 H, H_6, $J_{6,7}$ = 9 Hz, $J_{4,6}$ = 2.4 Hz), 7.45 (d, 1 H, H_4, $J_{4,6}$ = 2.4 Hz), 7.60–8.1 (m, 6 H), 8.15 (s, 1 H), 8.45–8.6 (d, 1 H, H_1, $J_{1,2}$ = 9 Hz), 8.6–8.75 (m, 1 H). Anal. Calcd for $C_{20}H_{12}O$: C, 89.52; H, 4.51. Found: C, 89.33; H, 4.30.

2-Methoxy-11*H*-benzo[*b*]fluoren-11-one (22). The reaction of 6-methoxy-1-indanone[16] (1.62 g, 10 mmol) and *o*-phthalaldehyde (**26**, 1.34 g, 10 mmol) in CH_3OH (50 mL) was effected as described for preparation of **28**. The reaction mixture was worked up as usual to yield 0.8 g of pure **22** (30%): mp 200–201 °C; NMR δ 3.38 (s, 3 H), 7.1–7.3 (m, 2 H), 7.4–7.9 (m, 6 H), 8.05 (d, 1 H); MS, *m/e* (relative intensity) 260 (M^+, 100). Anal. Calcd for $C_{18}H_{12}O_2$: C, 83.05; H, 4.65. Found: C, 82.80; H, 4.72.

2-Methoxy-11-hydroxy-11-[2-(1,3-dioxolan-2-yl)ethyl]-benzo[*b*]fluorene (23). A Grignard reagent prepared from 2-(2-bromoethyl)-1,3-dioxolane (1.8 g, 10 mmol) and Mg (0.2 g, 10 mmol) in THF (50 mL) was added dropwise to a solution of **22** (2.6 g, 10 mmol) in THF. After being stirred for 1 h at room temperature, the mixture was worked up as usual to yield 1.2 g, 33%, of **23**, which was used directly in the next step: mp 216–217 °C; MS, *m/e* (relative intensity) 362 (M^+, 8.5) 261 (100).

3-Methoxybenzo[*k*]fluoranthene (24). A suspension of **23** (0.36 g, 1 mmol) in 70% H_2SO_4 (10 mL) was allowed to stir at room temperature for 12 h. The mixture was poured onto ice and the suspension extracted with ether. The organic layer was washed with H_2O and 5% $NaHCO_3$ solution until neutral. After the mixture was dried ($MgSO_4$), the solvent was removed under reduced pressure to give an oily product, which was chromatographed on silica gel with hexane/CH_2Cl_2 (60:40), affording 84 mg (30%) of **24**: mp 210–212 °C; NMR δ 4.25 (s, 3 H), 7.05 (d, 1 H, H_2, $J_{1,2}$ = 8 Hz), 7.5–7.7 (m, 4 H), 7.85 (d, 1 H, H_1, $J_{1,2}$ = 8 Hz), 7.95–8.35 (m, 4 H), 8.45 (d, 1 H); MS, *m/e* (relative intensity) 282 (M^+, 100). Anal. Calcd for $C_{21}H_{14}O$: C, 89.33; H, 4.90. Found: C, 89.06; H, 4.75.

3-Hydroxybenzo[*k*]fluoranthene (25). The reaction of **24** (70 mg, 0.25 mmol) and BBr_3 (0.25 g, 1 mmol) in CH_2Cl_2 was effected as described for preparation of **5**. The crude phenol was purified by chromatography on silica gel with elution by CH_2Cl_2/hexane (50:50), giving pure **25** (40 mg, 59%): mp 239–240 °C; NMR δ 7.05 (d, 1 H, *J* = 8 Hz), 7.35–8.2 (m, 9 H), 8.25 (s, 1 H); MS, *m/e* (relative intensity) 268 (M^+, 100). Anal. Calcd for $C_{20}H_{12}O$: C, 89.52; H, 4.51. Found: C, 89.31; H, 4.50.

3-Methoxy-11*H*-benzo[*b*]fluoren-11-one (28). A solution of *o*-phthalaldehyde (**26**) (1.34 g, 10 mmol) and 5-methoxy-1-indanone (**27**, 1.62 g, 10 mmol)[17] in CH_3OH (50 mL) was heated at reflux for 30 min. A 30% solution of KOH in 20 mL of CH_3OH was then added dropwise during reflux, and refluxing was continued for 3 h. The product **28** separated as a yellow crystalline material (1.2 g, 46%): mp 145–146 °C; NMR δ 3.85 (s, 3 H), 6.7–6.8 (d, 1 H, H_2, $J_{1,2}$ = 8.0 Hz), 7.10 (d, 1 H), 7.2 (s, 1 H), 7.35–7.85

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(m, 5 H), 8.1 (s, 1 H); MS, *m/e* (relative intensity) 260 (M^+, 100), 231 (12.7), 217 (26.6). Anal. Calcd for $C_{18}H_{12}O_2$: C, 83.05; H, 4.65. Found: C, 82.95; H, 4.57.

3-Methoxy-11*H*-benzo[*b*]fluorene (29). A mixture of 2.6 g (10 mmol) of **28** and 5 mL of hydrazine hydrate was stirred in 100 mL of diethylene glycol for 10 min, then 10 mL of 40% KOH solution was added dropwise, and the mixture was refluxed for 4 h. The reaction mixture was worked up in the usual manner. The crude product was purified by chromatography on silica gel with elution by hexane/CH_2Cl_2 (80:20) to afford **29** (1.75 g, 71%), as a white solid: mp 146–147 °C; NMR δ 4.0 (s, 3 H), 4.1 (s, 2 H), 6.9–7.1 (d, 1 H), 7.35 (s, 1 H), 7.4–7.65 (m, 3 H), 7.85–8.05 (m, 3 H), 8.25 (s, 1 H); MS, *m/e* (relative intensity) 246 (M^+, 100). Anal. Calcd for $C_{18}H_{14}O$: C, 87.77; H, 5.72. Found: C, 87.41; H, 5.79.

3-Methoxy-11*H*-benzo[*b*]fluorene-11-carboxylic Acid (30). *n*-BuLi (10 mL, 1.6 M solution in hexane, Aldrich) was added slowly to a cold solution of **29** (2.46 g, 10 mmol) in dry ether (100 mL) under an N_2 atmosphere. The reaction mixture was stirred for 4 h at room temperature and then poured slowly onto powdered CO_2. The resulting mixture was acidified with dilute HCl and extracted with EtOAc. Removal of the solvent afforded **30** (1.75 g, 60%), as a white solid: mp 252–253 °C; NMR δ 4.0 (s, 3 H), 5.05 (s, 1 H), 6.95 (s, 1 H), 7.5–7.75 (m, 3 H), 7.85–8.0 (m, 3 H), 8.2 (s, 2 H); MS, *m/e* (relative intensity) 290 (M^+, 16), 245 (91).

3-Methoxy-11*H*-11-carbomethoxybenzo[*b*]fluorene (31). A mixture of 2.9 g (10 mmol) of **30** in 150 mL of CH_3OH was refluxed with 3 drops of concentrated H_2SO_4. After 3 h, the solution became clear and was then poured into H_2O and extracted with EtOAc. Removal of the solvent afforded **31** as a crystalline material (2.5 g, 82%): mp 113–114 °C; NMR δ 3.7 (s, 3 H), 3.9 (s, 3 H), 4.95 (s, 1 H), 6.8–7.0 (m, 1 H), 7.3–8.2 (m, 8 H); MS, *m/e* (relative intensity) 304 (M^+, 38), 246 (25). Anal. Calcd for $C_{20}H_{15}O_3$: C, 79.18; H, 4.98. Found: C, 79.30; H, 4.63.

Methyl 11-(Methoxycarbonyl)-3-methoxy-11*H*-benzo[*b*]fluorene-11-propanoate (32). A mixture containing 3.04 g (10 mmol) of **31**, 0.54 g (10 mmol) of NaOMe, and 1.0 g of methyl acrylate in 100 mL of dry CH_3OH was stirred at 0 °C for 3 h. The reaction mixture was poured into ice-cold water and extracted with CH_2Cl_2. The organic layer was dried over $MgSO_4$ and concentrated. The crude product was purified by chromatography on silica gel, eluted with hexane/CH_2Cl_2 (70:30) to give **32** (2.4 g, 61%) as a solid: mp 129–130 °C; NMR δ 1.6–1.8 (m, 2 H), 2.5–2.8 (m, 2 H), 3.6 (s, 6 H), 3.95 (s, 3 H), 6.8–7.0 (m, 1 H), 7.3–7.6 (m, 4 H), 7.8–8.0 (m, 3 H), 8.1 (d, 1 H); MS, *m/e* (relative intensity) 390 (M^+, 32.6), 331 (100), 271 (70), 261 (48).

3-Methoxy-11*H*-benzo[*b*]fluorene-11-propionic Acid (33). The above diester **32** (1.95 g, 5 mmol), ethoxyethanol (50 mL), and 40% aqueous KOH were heated under reflux for 3 h. The reaction mixture was then poured into H_2O and extracted with Et_2O (2 × 50 mL). The Et_2O layer was washed with H_2O, and the aqueous phase was acidified with concentrated HCl. Extraction with EtOAc and standard workup gave 1.1 g (69%) of **33** as a white solid: mp 158–159 °C; MS, *m/e* (relative intensity) 318 (M^+, 27), 260 (65), 245 (100), 230 (27.2).

6-Methoxy-1-oxo-1,2,3,3a-tetrahydro-BbF (34). Oxalyl chloride (1.89 g, 15 mmol) was added dropwise to a suspension of the acid **33** (1.6 g, 5 mmol) in dry CH_2Cl_2 (50 mL). The mixture was stirred for 1 h at room temperature, and then the solvent was removed. The crude product was dissolved in 150 mL of CS_2, and the solution was cooled to 0 °C in an N_2 atmosphere. $AlCl_3$ (1.9 g, 15 mmol) was added in portions, and the mixture was stirred at room temperature for 2 h and then heated under reflux for 30 min. The solution was then poured into ice–water containing 10 mL of 4 N HCl. The resulting mixture was extracted with CH_2Cl_2. The organic layer was washed with H_2O, dried ($MgSO_4$), and concentrated to give 1.25 g of **34**: mp 157–158 °C; NMR δ 2.8–3.3 (m, 4 H), 4.15 (s, 3 H), 4.2–4.4 (m, 1 H), 7.2 (dd, 1 H), 7.6–8.3 (m, 6 H), 8.5 (s, 1 H); MS, *m/e* (relative intensity) 300 (M^+, 100), 273 (25), 200 (66), 149 (57). Anal. Calcd for $C_{21}H_{16}O_2$: C, 83.97; H, 5.37. Found: C, 83.74; H, 5.21.

1-Hydroxy-6-methoxy-1,2,3,3a-tetrahydro-BbF (35). A solution of the above ketone **34** (1.5 g, 5 mmol) in THF (50 mL) was stirred with $NaBH_4$ (0.34 g, 10 mmol) at ambient temperature for 1 h. The reaction mixture was then poured into H_2O and the aqueous phase extracted with EtOAc (3 × 100 mL). The EtOAc extract was washed with H_2O and dried ($MgSO_4$). Removal of the solvent afforded **35** (1.3 g, 85%) as a white solid: mp 152–153 °C; MS, *m/e* (relative intensity) 302 (M^+, 20), 258 (100).

6-Methoxy-BbF (36). A solution of **35** (1.5 g, 5 mmol) and PTSA (5 mg) in benzene was heated at reflux for 30 min by using a Dean–Stark apparatus. The reaction mixture was worked up in the usual manner to give 1.4 g of olefin: mp 117–118 °C; MS, *m/e* (relative intensity) 284 (M^+, 100), 139 (28).

A solution of the above olefin and DDQ (1.1 g, 5 mmol) in dry benzene was heated at reflux for 1 h. The reaction mixture was worked up in the usual manner. The crude product was purified by chromatography on silica gel and eluted with hexane/CH_2Cl_2 (70:30) to afford 6-methoxy-BbF (**36**) (0.85 g, 60%) as a yellow solid: mp 145–146 °C; NMR δ 3.95 (s, 3 H), 6.8–7.0 (dd, 1 H), 7.45–7.85 (m, 6 H), 7.9–8.0 (m, 1 H), 8.15 (s, 1 H), 8.25–8.55 (dd, 1 H), 8.5–8.65 (m, 1 H); MS, *m/e* (relative intensity) 282 (M^+, 100), 267 (56), 248 (5), 239 (8.6). Anal. Calcd for $C_{21}H_{14}O$: C, 89.33; H, 4.99. Found: C, 89.12; H, 4.86.

6-Hydroxy-BbF (6). 6-Methoxy-BbF (**36**, 0.28 g, 1 mmol) was converted to **6** as described for the preparation of **5**. The crude product was purified by chromatography on silica gel with elution by hexane/CH_2Cl_2 (50:50) to afford **6** (0.2 g, 74%) as a yellow solid: mp 232–233 °C; NMR δ 6.85–7.15 (dd, 1 H, H_5, $J_{4,5}$ = 8.0 Hz, $J_{5,7}$ = 2.0 Hz), 7.58 (d, 1 H), 7.6–8.2 (m, 6 H), 8.25 (s, 1 H), 8.3–8.45 (dd, 1 H), 8.6–8.8 (m, 1 H); MS, *m/e* (relative intensity) 268 (M^+, 100), 240 (16) 239 (44). Anal. Calcd for $C_{20}H_{12}O$: C, 89.52; H, 4.51. Found: C, 89.39; H, 4.72.

Synthesis of 5- and 6-Hydroxy-BbF (5 and 6) from 18. Acephenanthrylene (**18**, 0.2 g, 1 mmol), butadiene (2 mL), and hydroquinone (5 mg) were heated in a sealed tube at 160 °C for 30 h. The reaction mixture was dissolved in CH_2Cl_2 (100 mL) and washed with 5% aqueous NaOH (2 × 50 mL) and H_2O, dried ($MgSO_4$), and concentrated to afford 100 mg of tetrahydro compound **37** as a yellow oil. The crude mixture was purified by chromatography on silica gel with elution by hexane to give 3b,4,7,7a-tetrahydro-BbF (**37**) as a yellow oil (60 mg, 23%): MS, *m/e* (relative intensity) 256 (M^+, 26), 202 (100).

The above compound was dissolved in dry THF (10 mL) and 0.8 g (4.6 mmol) of *m*-chloroperbenzoic acid was added. The reaction mixture was stirred for 2 h at room temperature under N_2 and then worked up in the usual manner to give the crude epoxide, which was used directly in the next step.

The above epoxide **38** was dissolved in benzene (10 mL), and 0.45 g (2 mmol) of DDQ was added. The reaction mixture was heated at reflux for 30 min in an atmosphere of N_2. The residue obtained after removal of the benzene was purified by chromatography on silica gel. Elution with CH_2Cl_2/hexane (50:50) afforded a mixture of **5** and **6** (20 mg), which were separated by HPLC.

8-Hydroxy-BbF (8). A solution of 7b,8-dihydro-7b,8-dihydroxy-BbF (**39**, 0.15 g, 0.5 mmol)[10] and PTSA (10 mg) in benzene was heated at reflux for 30 min by using a Dean–Stark trap. Conventional workup followed by chromatography on silica gel and elution with hexane/CH_2Cl_2 (50:50) afforded **8** (0.1 g, 74%) as a white solid: mp 209–210 °C; NMR δ 7.3–7.5 (m, 2 H), 7.55–7.8 (m, 3 H), 7.9–8.1 (m, 2 H), 8.3–8.75 (m, 4 H); MS, *m/e* (relative intensity) 268 (M^+, 100), 239 (15). Anal. Calcd for $C_{20}H_{12}O$: C, 89.52; H, 4.51. Found: C, 89.30; H, 4.63.

9-Hydroxy-BbF (9). The conversion of 9-oxo-9,10,11,12-tetrahydro-BbF (**40**, 0.14 g, 0.5 mmol)[11] to the corresponding phenol **9** was carried out as described for the preparation of **1**. The crude product was purified by chromatography on silica gel with elution by CH_2Cl_2/hexane (50:50) to afford **9** (60 mg, 44.7%): mp 221–222 °C; NMR δ 7.05 (dd, 1 H, H_{10}, $J_{10,11}$ = 8.0 Hz, $J_{10,12}$ = 2.0 Hz), 7.3–8.15 (m, 7 H), 8.3 (dd, 1 H), 8.5 (dd, 1 H), 8.75 (s, 1 H); MS, *m/e* (relative intensity) 268 (M^+, 100), 239 (15). Anal. Calcd for $C_{20}H_{12}O$: C, 89.52; H, 4.51. Found: C, 89.70; H, 4.61.

9-(2-Bromo-5-methoxybenzylidene)fluorene (43). 2-Bromo-5-methoxybenzaldehyde (**41**, 2.15 g, 10 mmol)[18] was added to a suspension of fluorene (**42**, 1.65 g, 10 mmol) and *t*-BuOK (1.2 g, 10 mmol) in *t*-BuOH (50 mL) at 40 °C. The reaction mixture

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was stirred at 50 °C for 3 h, poured into H_2O, and extracted with CH_2Cl_2 (3 × 100 mL). The organic layers were washed with H_2O and dried, giving **43** as a yellow solid. This crude compound was purified by chromatography on silica gel with elution by hexane to afford unreacted fluorene (0.5 g) and, after further elution by hexane/CH_2Cl_2 (70:30), pure **43** (1.8 g, 50%): mp 90–91 °C; NMR δ 3.77 (s, 3 H), 6.84 (dd, 1 H), 7.1 (dd, 1 H), 7.15–7.9 (m, 10 H); MS, *m/e* (relative intensity) 364 (M^+, 8.1), 283 (39.7). Anal. Calcd for $C_{21}H_{15}BrO$: C, 69.43; H, 4.16; Br, 21.96. Found: C, 69.36; H, 4.32; Br, 21.60.

10-Methoxy-BbF (44). A solution of **43** (0.36 g, 1 mmol) and KOH (0.56 g, 10 mmol) in quinoline was heated at reflux for 3 h. The reaction mixture was then poured into ice, acidified by adding concentrated H_2SO_4, and extracted with CH_2Cl_2 (4 × 100 mL). The organic layers were washed with H_2O, dried ($MgSO_4$), and concentrated, affording **44** as a dark yellow compound. This crude product was purified by chromatography on silica gel with elution by CH_2Cl_2/hexane (20:80) to afford 10-methoxy-BbF (**44**) as a yellow solid (0.19 g, 67%): mp 198–199 °C; NMR δ 4.0 (s, 3 H), 7.2–7.45 (m, 4 H), 7.65–8.0 (m, 4 H), 8.13 (s, 1 H, H_8), 8.35 (d, 1 H, H_1), 8.52 (d, 1 H, H_{12}); MS, *m/e* (relative intensity) 282 (M^+, 100). Anal. Calcd for $C_{21}H_{14}O$: C, 89.33; H, 4.99. Found: C, 89.67; H, 4.85.

10-Hydroxy-BbF (10). A solution of BBr_3 (0.25 g, 1 mmol) in CH_2Cl_2 was added via a syringe to a stirred solution of **44** (0.28 g, 1 mmol) in CH_2Cl_2 at 0 °C under N_2. A dark color developed within 10 min, and the mixture was stirred for a further 8 h to complete the reaction. The reaction mixture was then poured into ice. The organic layer was washed with aqueous $NaHCO_3$ (3 × 100 mL) and H_2O, dried ($MgSO_4$), and concentrated to give the crude phenol **10**. This crude phenol was purified by chromatography on silica gel with elution by CH_2Cl_2/hexane (50:50) to afford 10-hydroxy-BbF (0.1 g, 37%) as a yellow solid: mp 229–230 °C; NMR δ 7.25 (dd, 1 H, H_{11}, $J_{10,11}$ = 9 Hz, $J_{9,11}$ = 3 Hz), 7.35–7.5 (m, 3 H), 7.74 (d, 1 H), 7.8–8.05 (m, 3 H) 8.1 (s, 1 H, H_8), 8.32 (d, 1 H), 8.45 (d, 1 H); MS, *m/e* (relative intensity) 268 (M^+, 100), 240 (8.2), 239 (9). Anal. Calcd for $C_{20}H_{12}O$: C, 89.52; H, 4.51. Found: C, 89.32; H, 4.70.

9-(2-Bromo-4-methoxybenzylidene)fluorene (46). The reaction of fluorene (**42**, 0.5 g, 3 mmol), 2-bromo-4-methoxybenzaldehyde (**45**, 0.64 g, 3 mmol),[19] and *t*-BuOK (0.34 g, 3 mmol) in *t*-BuOH (50 mL) was effected as described for **43**. The crude product was purified by chromatography on silica gel, with elution by hexane to give fluorene and then further elution by CH_2Cl_2/hexane (20:80), affording pure **46** (0.5 g, 45%): mp 123–124 °C; NMR δ 3.75 (s, 3 H), 6.9 (dd, 1 H), 7.06 (dd, 1 H), 7.2–7.88 (m, 10 H); MS, *m/e* (relative intensity) 364 (M^+, 81.3), 362 (80.6), 283 (23), 239 (100). Anal. Calcd for $C_{21}H_{15}BrO$: C, 69.43; H, 4.16; Br, 21.96. Found: C, 69.58; H, 4.30; Br, 21.63.

11-Methoxy-BbF (47). The reaction of **46** (0.36 g, 1 mmol) and KOH (0.56 g, 10 mmol) in quinoline was effected as described for preparation of **44**. The crude product was purified by chromatography on silica gel. Elution with hexane/CH_2Cl_2 (70:30) gave pure **47** (0.15 g, 53%): mp 181–182 °C; NMR δ 4.0 (s, 3 H), 7.15–7.45 (m, 3 H), 7.65–8.05 (m, 6 H), 8.12 (s, 1 H, H_8), 8.37 (d, 1 H); MS, *m/e* (relative intensity) 282 (M^+, 100), 262 (32), 239 (72). Anal. Calcd for $C_{21}H_{14}O$: C, 89.33; H, 4.99. Found: C, 88.98; H, 4.81.

11-Hydroxy-BbF (11). The reaction of **47** (0.14 g, 0.5 mmol) and BBr_3 (0.25 g, 1 mmol) in CH_2Cl_2 was effected as described for preparation of **10**. The crude product was purified by chromatography on silica gel with elution by CH_2Cl_2/hexane (50:50) to give pure **11** (70 mg, 53%): mp 215–216 °C; NMR δ 7.2 (dd, 1 H, H_{10}, $J_{9,10}$ = 9 Hz, $J_{10,12}$ = 2 Hz), 7.29–7.48 (m, 2 H), 7.6–8.05 (m, 6 H), 8.1 (s, 1 H, H_8), 8.34 (d, 1 H); MS, *m/e* (relative intensity) 268 (M^+, 100), 239 (31). Anal. Calcd for $C_{20}H_{12}O$: C, 89.52; H, 4.51. Found: C, 89.56; H, 4.66.

12-Hydroxy-BbF (12). 12-Oxo-9,10,11,12-tetrahydro-BbF (**48**, 0.1 g, 0.36 mmol)[7] was converted to **12** as described above for **1**. The crude product was purified by chromatography on silica gel with elution by hexane/CH_2Cl_2 (50:50) to give a light yellow solid (62 mg, 64%): mp 214–215 °C; NMR δ 7.30 (dd, 1 H, H_{11}, $J_{10,11}$ = 8.0 Hz, $J_{9,11}$ = 2 Hz), 7.35–8.0 (m, 8 H), 8.23 (s, 1 H, H_8), 9.45 (dd, 1 H, H_1, $J_{1,2}$ = 8.0 Hz, $J_{1,3}$ = 1.5 Hz); MS, *m/e* (relative intensity) 268 (M^+, 100), 239 (39). Anal. Calcd for $C_{20}H_{12}O$: C, 89.52; H, 4.51. Found: C, 89.26; H, 4.70.

Conversion of Hydroxy-BbFs to Their Trimethylsilyl Derivatives. The phenol **1** (1 mg) was dissolved in 1 mL of dry THF. A 0.1-mL aliquot was silylated by heating with 0.2 mL of Regisil RC-2 in a 1 mL Reactivial (Pierce Chemical Co., Rockford, IL) at 80 °C for 1 h. A 20-μL aliquot of this silylation mixture was analyzed by capillary GC. In a similar manner, compounds **2–12** were converted to their corresponding trimethylsilyl derivatives and analyzed by capillary GC.

Registry No. **1**, 100516-03-8; **1** (trimethylsilyl derivative), 100516-43-6; **2**, 100516-04-9; **2** (trimethylsilyl derivative), 100516-44-7; **3**, 100516-05-0; **3** (trimethylsilyl derivative), 100516-45-8; **4**, 81824-15-9; **4** (trimethylsilyl derivative), 100516-46-9; **5**, 81824-14-8; **5** (trimethylsilyl derivative), 100516-47-0; **6**, 81824-09-1; **6** (trimethylsilyl derivative), 100516-48-1; **7**, 81824-10-4; **7** (trimethylsilyl derivative), 100516-49-2; **8**, 41940-31-2; **8** (trimethylsilyl derivative), 100516-50-5; **9**, 100516-06-1; **9** (trimethylsilyl derivative), 100516-51-6; **10**, 100516-07-2; **10** (trimethylsilyl derivative), 100516-52-7; **11**, 100516-08-3; **11** (trimethylsilyl derivative), 100570-93-2; **12**, 100516-09-4; **12** (trimethylsilyl derivative), 100516-53-8; **13**, 88746-52-5; **14**, 100516-10-7; **15**, 100516-11-8; **16**, 100516-12-9; **17**, 100516-13-0; **17** (3,3a-epoxide), 100516-33-4; **18**, 201-06-9; **19**, 6630-33-7; **20**, 7235-14-5; (*E*)-**21**, 100516-14-1; (*Z*)-**21**, 100516-38-9; **22**, 100516-15-2; **23**, 100516-16-3; **24**, 100516-17-4; **25**, 100516-18-5; **26**, 643-79-8; **27**, 5111-70-6; **28**, 100516-19-6; **29**, 100516-20-9; **30**, 100516-21-0; **31**, 100516-22-1; **32**, 100516-23-2; **33**, 100516-24-3; **33** (acid chloride), 100516-41-4; **34**, 100516-25-4; **35**, 100516-26-5; **36**, 100516-27-6; **37**, 100570-92-1; **38**, 100516-28-7; **39**, 57393-19-8; **40**, 77061-01-9; **41**, 7507-86-0; **42**, 86-73-7; **43**, 100516-29-8; **44**, 100516-30-1; **45**, 43192-31-0; **46**, 100516-31-2; **47**, 100516-32-3; **48**, 88746-63-8; 3,3a-dihydro-Bbf, 88746-54-7; 4-acetoxy-3b,4,7,7a-tetrahydro-Bbf, 100516-34-5; 7-acetoxy-3b,4,7,7a-tetrahydro-Bbf, 100516-35-6; 4-acetoxy-Bbf, 100516-36-7; 7-acetoxy-Bbf, 100516-37-8; 2-methoxy-Bbf, 100516-39-0; 5-methoxy-Bbf, 100516-40-3; 3,3a-dihydro-6-methoxy-Bbf, 100516-42-5; 1-acetoxybutadiene, 1515-76-0; 6-methoxy-1-indanone, 13623-25-1; 2-(2-bromoethyl)-1,3-dioxolane, 18742-02-4; methyl acrylate, 96-33-3; butadiene, 106-99-0; Regisil RC-2, 100603-73-4.

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