Synthesis of Benzo[*a*]pyren-6-yl-Substituted Carboxylic Acids

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The title compounds were synthesized from benzo[*a*]pyrene in three to four steps, depending on the chain length of the carboxylic acid. After iodination, alkanone chains were introduced by special Heck reactions. Transformation into carboxylic acids was achieved by haloform reaction and by Willgerodt–Kindler reaction.

Introduction

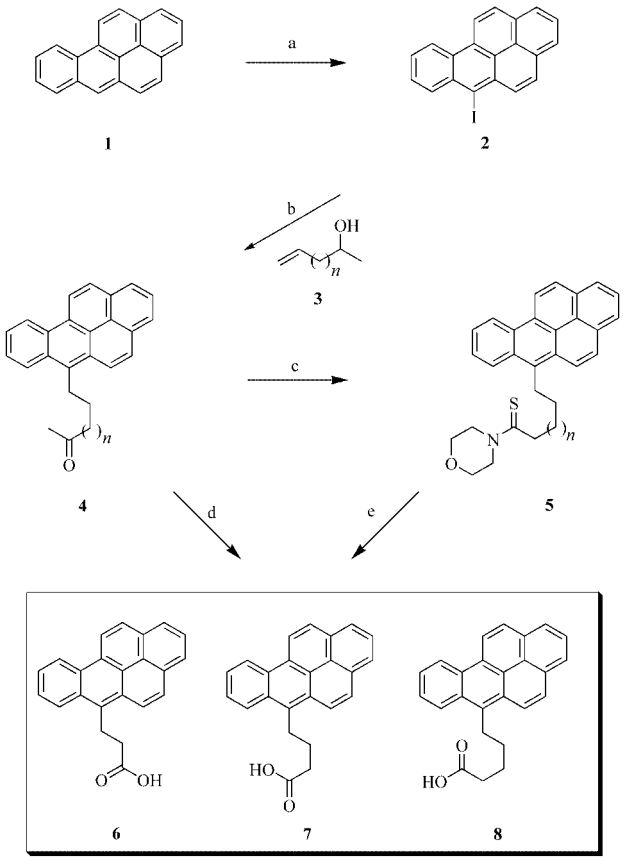
Benzo[*a*]pyrene (**1**) − abbreviated as B[*a*]P − is one of the most potent carcinogenic polycyclic aromatic hydrocarbons.[1−3] Analytical chemistry is therefore in need of methods that will allow the reliable measurement of its concentration in water in the range of less than 10 ng/l. An appropriate immunoassay should be the method of choice. For the generation of monoclonal antibodies with the required selectivity for **1**, immunogens made from suitable B[*a*]P derivatives are indispensable, and the title compounds are promising candidates for this purpose. Here we report on the synthesis of the three homologous B[*a*]P-substituted carboxylic acids **6**, **7** and **8**. For comparison, related studies for the generation of monoclonal antibodies for **1** have also employed alkanoic acids, but either with B[*a*]Ps substituted in the 1-position[4] or with disadvantageous heteroatoms in the chain.[5]

Results and Discussion

The 6-position of B[*a*]P (**1**) is the most electrophilic, but is sterically somewhat hindered.[6−8] Nevertheless, our intention was to introduce a sterically rather demanding iodine into the 6-position, in order to make use of Heck-type reactions for the introduction of a functionalized side chain. Alternative methods for the final transformation into a carboxylic acid should give access to a variety of model compounds with different chain lengths.

Initial attempts to iodinate **1** with iodide under acidic conditions as described by Tye et al.[9] were unsatisfactory in our hands because of insufficient regioselectivity. *N*-iodosuccinimide (NIS) supported by acidic aluminium oxide turned out to be a superior reagent, giving access to 6-iodo-B[*a*]P (**2**) in 80% yield.

The Heck reaction with allylic and homoallylic alcohols such as **3a** ($n = 0$) and **3b** ($n = 1$) is a well established method for the introduction of alkanone chains,[10−12] and the B[*a*]P derivatives **4** were indeed also obtained in good to excellent yields (Scheme 1). The initial carbopalladation



Scheme 1. a: NIS, Al_2O_3, toluene 20 °C, 4 days, 80%; b: 3, $Pd(OAc)_2$, LiCl, NEt_3, DMF, 120 °C, 14 h, $n = 0$: 76%, $n = 1$: 94%; c: sulfur, morpholine, 140 °C, 6 h, $n = 0$: 39%, $n = 1$: 19%; d: Br_2, NaOH, dioxane, 20 °C, 6 h, 56%; e: KOH, 2-methoxyethylene glycol, reflux, 6 h, $n = 0$: 39%, $n = 1$: 58%

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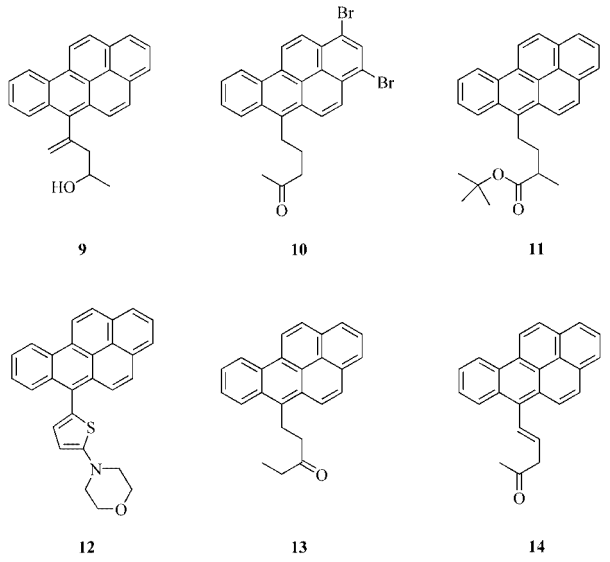
of this process regularly takes place highly regioselectively, with C−C bond formation at the terminal olefinic carbon.

However, a small amount of less than 3% of the isomeric alcohol **9** was also isolated and characterized (Scheme 2).

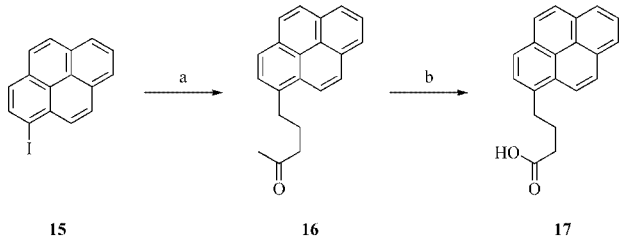


9 **10** **11**

12 **13** **14**

Scheme 2. Isolated and characterized by-products

In order to transform the obtained alkanones **4** into the desired carboxylic acids we planned to make use both of the haloform reaction[13−15] and of the Wilgerodt−Kindler reaction.[16−18] The propanoic acid **6** was obtained from the bromoform reaction of the butanone **4a** ($n = 0$) in an acceptable yield, an aqueous hypobromide solution, freshly prepared from bromine, KOH and water and mixed with dioxane, being applied at 0 °C in this case. Surprisingly, pentanone **4b** ($n = 1$) was completely inert under the same reaction conditions. An increase in the amount of bromine, though, gave a 71% yield of the barely soluble dibromide **10**. The reasons for the inertness of the α-acidic protons of **4b** remains unclear: there is no obvious increase in steric hindrance in relation to **4a**. Actually, one would assume a higher reactivity for **4b**, since the distance of the keto functionality from the sterically demanding aromatic moiety is larger than in the case of **4a**. For comparison we synthesized the pyranyl-substituted pentanone **16** (as outlined in Scheme 3), which smoothly underwent the bromoform reaction under moderate conditions. Both the particular length of the pentanone moiety and the double *peri*-position of this chain seem to be necessary for the observed inertness. Compound **4b** also proved to be inert for the iodoform reaction[19] under moderate conditions with either KOH or with pyridine as base. Under forced reaction conditions with potassium *tert*-butoxide as a stronger base in refluxing *tert*-butanol, a monoiodination obviously takes place, since the only isolated product **11** clearly derives from a Favorskii rearrangement.[20−22]



15 **16** **17**

Scheme 3. Model study starting from pyrene: sequence of Heck reaction and haloform reaction; a: **3b**, $Pd(OAc)_2$, LiCl, NEt_3, DMF, 120 °C, 14 h, $n = 1$: 63%; b: Br_2, NaOH, dioxane, 20 °C, 6 h, 79%

The failure of the haloform reactions in the case of **4b** made us look for an alternative pathway to the butanoic acid **7**. The Wilgerodt−Kindler reaction is a rather complex domino process, involving several redox reaction steps in an alkanone chain; after hydrolysis of an thioamide as intermediary product one obtains a carboxylic acid with the same number of carbon atoms as the initial alkanone.[23−24] The oxidizing conditions of this process are compatible with the sensitive B[*a*]P nucleus.[25] Therefore, butanone **4a** was chosen as starting material for the desired butanoic acid **7**, and indeed, heating of **4a** with sulfur in morpholine at 140 °C resulted in the formation of the thioamide **5a** as the main product in moderate yield, with the terminal carbon atom already in the right oxidation state. The thiophene **12**, isolated in 15% yield, is a regular by-product of this kind of process. For the hydrolysis of **5a**, rather vigorous reaction conditions were necessary: potassium hydroxide in boiling 2-methoxyethanol was the reagent of choice. After chromatography over silica, the butanoic acid **7** was obtained in 39% yield. The analogous transformation of pentanone **4b** into the pentanoic acid **8** was also successful, but **4b** was also the substrate that caused the most problems in the Willgerodt−Kindler process. TLC showed that a multitude of products were formed, from which **13** and **14** were identified and characterized in addition to the 19% yield of the desired product **5b**. Luckily, the final hydrolysis step − although again under harsh conditions − proceeded with satisfactory results.

Conclusion

The overall yields, starting from the parent compound **1**, are 15% for the propanoic acid **6**, 46% for the butanoic acid **7** and 17% for the pentanoic acid **8**. The procedures presented are suitable for synthesis of B[*a*]P-substituted carboxylic acids on 100 mg scales in one run. The synthesized B[*a*]P derivatives **6**, **7** and **8** are designated for the development of a potent immunoassay based on monoclonal antibodies.

Experimental Section

General Remarks: M.p. (uncorrected): Reichert Thermovar. IR: Perkin−Elmer 841. NMR: Bruker DRX 400. ^1H NMR spectra (400 MHz) were recorded in $CDCl_3$, $(CD_3)_2CO$ or $[D_6]DMSO$ (**7a**, **7b**) with TMS as the internal standard. ^{13}C NMR spectra (100.6 MHz) were measured by use of $CDCl_3$, $(CD_3)_2CO$ or $[D_6]DMSO$ as the solvent and the internal standard. The assignments of the ^1H NMR and ^{13}C NMR signals are based on 2D

NMR techniques such as HMBC, HMQC and H,H COSY. MS: MAT 700 ITD (70 eV) and Varian MAT 311 A. For analytical TLC, precoated plastic sheets "POLYGRAM SIL G/UV254" from Macherey−Nagel were used. EA: Elementar/Hanau Vario EL.

Warning! *Because of the mutagenicity of B[a]P (**1**) and its derivatives, one must carefully avoid any contact of these substances with the skin and must prevent accidental inhalation of powder or contaminated dust by use of appropriate protection methods.*

All new compounds were pure according to their ^{1}H NMR spectra; because of the potential mutagenicity, elemental analyses were dispensed with.

6-Iodobenzo[*a*]pyrene (2): A suspension of B[*a*]P (**1**, 400 mg, 1.59 mmol), NIS (421 mg, 1.60 mmol) and acid alumina (10 g) in dry toluene (30 mL) was intensively stirred for 4 days. The alumina was filtered off and washed with CH_2Cl_2 (150 mL). The combined organic layers were extracted with Na_2SO_3 solution (50 mL), water (50 mL) and brine (50 mL). After the solution had been dried with $MgSO_4$, the solvents were distilled off and recrystallisation from petroleum ether (80/100) yielded **2** (480 mg, 1.27 mmol, 80%) as a pale yellow powder. R_f = 0.32 (silica, MTBE/petroleum ether, 1:29). IR (KBr): $\tilde{\nu}$ = 3046 cm^{-1} (w), 1250 (m), 899 (m), 836 (vs), 823 (s), 754 (s), 685 (m). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.82−7.87 (m, 2 H, 8-H, 9-H), 8.00 (dd, *J* = 8.0, 7.5 Hz, 1 H, 2-H), 8.00 (d, *J* = 9.5 Hz, 1 H, 4-H), 8.14 ("d", *J* = 7.5 Hz, 1 H, 3-H), 8.25 ("d", *J* = 8.0 Hz, 1 H, 1-H), 8.35 (d, *J* = 9.0 Hz, 1 H, 12-H), 8.54 (d, *J* = 9.5 Hz, 1 H, 5-H), 8.83−8.85 (m, 1 H, 7-H), 9.00−9.02 (m, 1 H, 10-H), 9.05 (d, *J* = 9.0 Hz, 1 H, 11-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 104.6 (s, C-6), 122.1 (d, C-11), 123.3 (d, C-10), 124.5 (s, C-12b), 124.6 (s, C-12c), 125.7 (d, C-3), 126.5 (2d, C-1, C-2), 126.7 (d, C-9), 127.9 (d, C-8), 128.1 (s, C-10a), 128.4 (d, C-12), 128.8 (s, C-10b), 130.3 (d, C-4), 131.3 (s, C-12a), 131.4 (s, C-3a), 132.8 (s, C-6a), 132.9 (s, C-5a), 133.6 (d, C-5), 134.6 (d, C-7) ppm. MS (EI): *m*/*z* (%) = 378 (100) [M$^+$], 251 (44), 250 (45), 224 (5), 125 (40).

4-(Benzo[*a*]pyren-6-yl)butan-2-one (4a): In a screw-cap vessel under argon, a solution of iodide **2** (150 mg, 0.4 mmol), the alcohol **3a** (70 μL, 1.4 mmol), $Pd(OAc)_2$ (10 mg, 0.04 mmol), LiCl (20 mg, 0.4 mmol) and NEt_3 (200 μL, 1.4 mmol) in dry DMF (15 mL) were heated to 120 °C for 14 h. After the mixture had cooled, toluene (80 mL) was added and the solution was extracted tree times with water (40 mL) and with brine (40 mL). Drying with $MgSO_4$, evaporation of the solvent and flash chromatography (silica, MTBE/petroleum ether, 1:2) yielded **4a** (98 mg, 0.30 mmol, 76%) as a pale yellow oil. R_f = 0.43 (silica, MTBE/petroleum ether, 1:2). IR (KBr): $\tilde{\nu}$ = 2930 cm^{-1} (w), 2866 (w), 1734 (s), 1495 (s), 1439 (s), 1176 (m), 826 (m). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.21 (s, 3 H, 1′-H), 2.95−2.99 (m, 2 H, 3′-H), 3.98−4.02 (m, 2 H, 4′-H), 7.78−7.83 (m, 2 H, 8-H, 9-H), 7.92 (d, *J* = 9.3 Hz, 1 H, 12-H), 7.94 ("t", *J* = 7.5 Hz, 1 H, 2-H), 8.04 (dd, *J* = 7.5, 1.0 Hz, 1 H, 1-H), 8.18 (dd, *J* = 7.5, 1.0 Hz, 1 H, 3-H), 8.20 (d, *J* = 10.0 Hz, 1 H, 4-H), 8.22 (d, *J* = 10.0 Hz, 1 H, 5-H), 8.45−8.47 (m, 1 H, 7-H), 8.99 (d, *J* = 9.3 Hz, 1 H, 11-H), 9.06−9.09 (m, 1 H, 10-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 22.2 (t, C-4′), 30.2 (q, C-1′), 44.8 (t, C-3′), 122.2 (d, C-11), 123.9 (d, C-10), 123.9 (s, C-12c), 124.1 (d, C-5), 124.6 (d, C-1), 124.9 (d, C-7), 125.6 (s, C-12b), 125.8 (d, C-3), 125.9 (s, C-5a), 125.9 (d, C-9), 126.2 (d, C-2), 126.6 (d, C-8), 126.7 (s, C-10b), 127.2 (d, C-4), 128.4 (s, C-10a), 128.5 (d, C-12), 129.6 (s, C-6a), 131.2 (s, C-3a), 131.6 (s, C-12a), 131.6 (s, C-6), 208.0 (s, C-2′) ppm. MS (EI): *m*/*z* (%) = 322 (12) [M$^+$], 278 (10), 265 (100), 251 (6), 250 (4), 43 (10).

5-(Benzo[*a*]pyren-6-yl)pentan-2-one (4b): By use of the same procedure as described for **4a** and by starting from the iodide **2** (270 mg, 0.70 mmol) and the homoallylic alcohol **3b**, compound **4b** (220 mg, 0.66 mmol, 94%) and the by-product **9** (4−5 mg, 0.015 mmol, 2%) were obtained. R_f = 0.65 (silica, ethyl acetate/petroleum ether, 1:3). IR (KBr): $\tilde{\nu}$ = 3039 cm^{-1} (w), 2925 (w), 2866 (w), 1717 (vs), 1461 (m), 1243 (m), 837 (m), 754 (s), 695 (m). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.15−2.23 (m, 2 H, 4′-H), 2.17 (s, 3 H, 1′-H), 2.66 (t, *J* = 6.9 Hz, 2 H, 3′-H), 3.75−3.79 (m, 2 H, 5′-H), 7.80−7.85 (m, 2 H, 8-H, 9-H), 7.95 (dd, *J* = 7.8, 7.3 Hz, 1 H, 2-H), 7.95 (d, *J* = 9.0 Hz, 1 H, 12-H), 8.06 (dd, *J* = 7.4, 1.0 Hz, 1 H, 1-H), 8.19 (dd, *J* = 7.8, 1.0 Hz, 1 H, 3-H), 8.26 (d, *J* = 9.4 Hz, 1 H, 4-H), 8.32 (d, *J* = 9.4 Hz, 1 H, 5-H), 8.60−8.62 (m, 1 H, 7-H), 9.04 (d, *J* = 9.0 Hz, 1 H, 11-H), 9.09−9.10 (m, 1 H, 10-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 25.0 (t, C-4′), 27.5 (t, C-5′), 30.2 (q, C-1′), 43.2 (t, C-3′), 122.2 (d, C-11), 123.7 (d, C-10), 123.9 (s, C-12c), 124.5 (d, C-5), 124.7 (d, C-1), 125.1 (d, C-7), 125.7 (2d, C-3,C-9), 126.1 (d, C-2), 126.3 (d, C-8), 126.6 (s, C-10b), 127.0 (d, C-4), 127.0 (s, C-12b), 127.4 (s, C-5a), 128.1 (d, C-12), 128.3 (s, C-10a), 130.0 (s, C-6a), 131.3 (s, C-3a), 131.6 (s, C-12a), 132.7 (s, C-6), 208.7 (s, C-2′) ppm. MS (EI): *m*/*z* (%) = 336 (39) [M$^+$], 278 (16), 265 (100), 251 (3), 250 (2), 43 (5).

By-Product 9: R_f = 0.48 (silica, ethyl acetate/petroleum ether, 1:3). IR (KBr): $\tilde{\nu}$ = 2964 cm^{-1} (m), 2930 (m), 2858 (w), 1458 (m), 1262 (m), 840 (s), 828 (m), 760 (s), 702 (m). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.17 (d, *J* = 6.0 Hz, 3 H, 1′$_a$-H), 1.21 (d, *J* = 6.0 Hz, 3 H, 1′$_b$-H), 2.13 (s, 1 H, OH), 2.81 ("t", *J* = 6.8 Hz, 2 H, 3′-H), 3.88−3.95 (m, 2 H, 2′-H), 5.46 (d, *J* = 3.0 Hz, 1 H, 5$_a$′-H), 5.99 (d, *J* = 3.0 Hz, 1 H, 5$_b$′-H), 7.80 ("t", *J* = 7.7 Hz, 1 H, 8-H), 7.83 ("t", *J* = 7.7 Hz, 1 H, 9-H), 7.91 (d, *J* = 9.5 Hz, 1 H, 12$_a$-H), 7.93 (d, *J* = 9.5 Hz, 1 H, 12$_b$-H), 7.97 ("t", *J* = 7.5 Hz, 1 H, 2-H), 8.07 ("d", *J* = 7.5 Hz, 1 H, 1$_a$-H), 8.08 ("d", *J* = 7.5 Hz, 1 H, 1$_b$-H), 8.19 ("d", *J* = 9.4 Hz, 1 H, 5$_a$-H), 8.23 ("d", *J* = 7.5 Hz, 2 H, 3-H, 5$_b$-H), 8.31 ("d", *J* = 9.4 Hz, 1 H, 4$_a$-H), 8.33 ("d", *J* = 9.4 Hz, 1 H, 4$_b$-H), 8.42 ("d", *J* = 7.7 Hz, 1 H, 7$_a$-H), 8.55 ("d", *J* = 8.0 Hz, 1 H, 7$_b$-H), 9.07 (d, *J* = 9.5 Hz, 1 H, 11-H), 9.09 ("d", *J* = 7.7 Hz, 1 H, 10-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 23.8 (q, C-1′), 49.3 (t, C-3′$_a$), 49.5 (t, C-3′$_b$), 65.6 (t, C-2′$_a$), 66.0 (t, C-2′$_b$), 119.9 (d, C-5′$_a$), 120.0 (d, C-5′$_b$), 122.1 (d, C-11′$_a$), 122.1 (d, C-11′$_b$), 123.2 (d, C-10$_a$), 123.2 (d, C-10$_b$), 124.8 (d, C-1$_a$), 124.9 (d, C-1$_b$), 125.8−126.2 (10 d, C-2$_{a/b}$, C-3$_{a/b}$, C-5$_{a/b}$, C-8$_{a/b}$, C-9$_{a/b}$), 126.9 (d, C-7$_a$), 127.0 (d, C-7$_b$), 127.4 (d, C-4$_a$), 127.5 (d, C-4$_b$), 128.0 (d, C-12$_{a/b}$), 131.6 (2d, C-2′$_{a/b}$), 144 (s, C-6$_{a/b}$) ppm. MS (EI): *m*/*z* (%) = 336 (58) [M$^+$], 318 (5), 291 (100), 276 (54), 265 (12), 252 (11). Because of hindered rotation of the C6/C4′ bond, compound **9** shows two data sets in the NMR, therefore subscipts "$_a$" and "$_b$" in the NMR assignments refer to pairs of signals of the rotamers. Singlets of minor intensity in the ^{13}C NMR could not be listed.

5-(Benzo[*a*]pyren-6-yl)-1-(morpholin-4-yl)butane-1-thione (5a): The ketone **4a** (100 mg, 0.31 mmol) was heated to 140 °C with sulfur (40 mg, 1.24 mmol) in dry morpholine for 6 h. After the mixture had cooled, toluene (100 mL) was added and the layer was washed twice with AcOH (10%, 40 mL), then with water (40 mL) and brine (40 mL). Drying with $MgSO_4$, evaporation of the solvent and chromatography (silica, MTBE/petroleum ether, 1:2) yielded **5a** (52 mg, 0.12 mmol, 39%) and the by-product **12** (20 mg, 0.05 mmol, 15%) as yellow oils. R_f = 0.44. IR (KBr): $\tilde{\nu}$ = 3042 cm^{-1} (m), 2963 (s), 2857 (s), 1488 (s), 1462 (s), 1280 (s), 990 (m), 840 (m), 828 (m), 759 (m), 693 (w). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.36 (tt, *J* = 8.2, 7.5 Hz, 2 H, 3′-H), 2.99 (t, *J* = 7.5 Hz, 2 H, 2′-H), 3.33−3.41 (m, 4 H, CH_2N), 3.70−3.73 (m, 2 H, CH_2O), 3.90 (t, *J* = 8.2 Hz, 2 H, 4′-H), 4.92−4.32 (m, 2 H, CH_2O), 7.79−7.84 (m, 2 H, 8-H, 9-H), 7.95 (d, *J* = 9.3 Hz, 1 H, 12-H), 7.96 (dd, *J* = 7.5, 7.0 Hz, 1 H, 2-H), 8.06 ("d", *J* = 7.0 Hz, 1 H, 1-H), 8.20 ("d", *J* = 7.5 Hz, 1 H, 3-H), 8.26 (d, *J* = 9.0 Hz, 1 H, 4-H), 8.28 (d, *J* = 9.0 Hz, 1 H, 5-

H), 8.54−8.56 (m, 1 H, 7-H), 9.03 (d, J = 9.0 Hz, 1 H, 11-H), 9.08−9.11 (m, 1 H, 10-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 27.2 (t, C-4′), 30.1 (t, C-3′), 42.6 (t, C-2′), 49.8 (t, CH_2N), 49.9 (t, CH_2O), 66.2 (t, CH_2N), 66.5 (t, CH_2O), 122.1 (d, C-11), 123.8 (s, C-12c), 123.8 (d, C-10), 124.3 (d, C-5), 124.8 (d, C-7), 124.8 (d, C-1), 125.6 (s, C-12b), 125.7 (d, C-9), 125.8 (d, C-3), 126.2 (d, C-2), 126.6 (d, C-8), 126.6 (s, C-5a), 127.2 (d, C-4), 127.5 (s, C-10b), 128.2 (d, C-12), 128.3 (s, C-10a), 129.8 (s, C-6a), 131.1 (s, C-3a), 131.6 (s, C-12a), 132.0 (s, C-6), 203.2 (s, C-1′) ppm. MS (EI): *m*/*z* (%) = 423 (35) [M$^+$], 278 (100), 265 (18), 250 (4).

By-Product 12: R_f = 0.88. IR (KBr): ṽ = 3041 cm^{-1} (w), 2926 (w), 2858 (w), 1616 (m), 1584 (m), 1464 (m), 1432 (m), 1114 (s), 1063 (m), 839 (s), 826 (m), 758 (m), 634 (m). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 3.22 (ddd, J = 9.5, 6.5, 2.4 Hz, 4 H, CH_2N), 3.85 (ddd, J = 9.5, 6.5, 2.4 Hz, 4 H, CH_2O), 6.29 (d, J = 3.5 Hz, 1 H, 3′-H), 6.87 (d, J = 3.5 Hz, 1 H, 4′-H), 7.63−7.67 (m, 1 H, 8-H), 7.73−7.75 (m, 1 H, 9-H), 7.79 (d, J = 9.5 Hz, 1 H, 12-H), 7.91 (“t”, J = 7.9 Hz, 1 H, 2-H), 7.98 (d, J = 9.0 Hz, 1 H, 5-H), 8.00 (“d”, J = 6.5 Hz, 1 H, 7-H), 8.17 (dd, J = 7.9 Hz, 1.0, 1 H, 1-H), 8.23 (dd, J = 7.9 Hz, 1.0, 1 H, 3-H), 8.28 (d, J = 9.0 Hz, 1 H, 12-H), 9.02 (d, J = 9.0 Hz, 2 H, 10-H, 11-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 50.5 (t, CH_2N), 65.5 (t, CH_2O), 104 (d, C-3′), 121.1 (d, C-11), 121.8 (d, C-10), 122.4 (s, C-12c), 124.1 (d, C-6), 124.1 (d, C-7), 124.4 (s, C-12b), 124.8 (d, C-1), 124.9 (d, C-9), 125.2 (d, C-5′), 125.2 (d, C-2), 125.2 (d, C-8), 125.7 (d, C-5), 126.5 (s, C-10b), 126.7 (d, C-3), 126.8 (s, C-10a), 127.0 (d, C-12), 127.0 (d, C-4), 127.6 (d, C-4′), 129.4 (s, C-5a), 130.2 (s, C-12a), 130.4 (s, C-3a), 131.2 (s, C-6a), 159.1 (s, C-2′) ppm. MS (EI): *m*/*z* (%) = 420 (100) [M$^+$], 402 (18), 333 (6), 265 (100), 251 (4), 250 (6), 239 (3).

5-(Benzo[*a*]pyren-6-yl)-1-(morpholin-4-yl)pentane-1-thione (5b): A solution of the ketone **4b** (370 mg, 1.1 mmol) and sulfur (100 mg, 3.3 mmol) in dry morpholine (50 mL) was heated under argon in a screw-cap vessel at 140 °C for 6 h. After the mixture had cooled, toluene (200 mL) was added and the layer was washed four times with HCl (10%, 50 mL) and then with water (50 mL) and brine (50 mL). The organic layer was dried with $MgSO_4$, the solvent was distilled off and the residue was fractionated by flash chromatography (silica, MTBE/petroleum ether, 1:1). Yield: 90 mg (0.21 mmol, 19%) of **5b**, 13 mg (0.04 mmol, 4%) of the starting material isomer **13** and 15 mg (0.05 mmol, 4%) of the olefin **14** as yellow oils. R_f = 0.35. IR (KBr): ṽ = 3041 cm^{-1} (m), 2961 (s), 2857 (s), 1637 (m), 1463 (s), 1431 (s), 1273 (m), 1114 (s), 961 (m), 839 (s), 826 (m), 758 (s), 693 (m). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.99−2.05 (m, 4 H, 3′-H, 4′-H), 2.92 (t, J = 7.3 Hz, 2 H, 2′-H), 3.50 (ddd, J = 9.2, 7.5, 1.0 Hz, 2 H, CH_2N), 3.57 (ddd, J = 9.2 Hz, 7.5, 1.0 Hz, 2 H, CH_2N), 3.71 (ddd, J = 9.2, 7.5, 2.0 Hz, 2 H, CH_2O), 3.82 (t, J = 7.5 Hz, 2 H, 5′-H), 4.30 (ddd, J = 9.2, 7.5, 2.0 Hz, 2 H, CH_2O), 7.81−7.85 (m, 2 H, 8-H, 9-H), 7.96 (d, J = 9.6 Hz, 1 H, 12-H), 7.96 (“t”, J = 7.5 Hz, 1 H, 2-H), 8.07 (dd, J = 7.5, 1.0 Hz, 1 H, 1-H), 8.21 (dd, J = 7.5, 1.0 Hz, 1 H, 3-H), 8.27 (d, J = 9.5 Hz, 1 H, 4-H), 8.30 (d, J = 9.5 Hz, 1 H, 5-H), 8.54−8.57 (m, 1 H, 7-H), 9.03 (d, J = 9.5 Hz, 1 H, 11-H), 9.10−9.12 (m, 1 H, 10-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 27.1 (t, C-5′), 28.6 (t, C-4′), 30.0 (t, C-3′), 42.50 (t, C-2′), 49.1 (t, CH_2N), 49.2 (t, CH_2O), 65.4 (t, CH_2N), 65.6 (t, CH_2O), 122.3 (d, C-11), 122.8 (d, C-10), 123.0 (s, C-12c), 123.5 (d, C-5), 123.7 (d, C-1), 123.7 (d, C-7), 124.7 (s, C-12b), 124.7 (d, C-9), 124.8 (d, C-3), 125.2 (d, C-2), 125.3 (d, C-8), 125.6 (s, C-5a), 126.1 (d, C-4), 126.3 (s, C-10b), 127.2 (d, C-12), 127.4 (s, C-10a), 128.9 (s, C-6a), 130.3 (s, C-3a), 130.7 (s, C-12a), 132.0 (s, C-6), 202.6 (s, C-1′) ppm. MS (EI): *m*/*z* (%) = 437 (44) [M$^+$], 421 (6), 404 (21), 292 (23), 277 (15), 265 (100), 252 (11), 172 (63).

By-Product 13: R_f = 0.74. IR (KBr): ṽ = 3041 cm^{-1} (w), 2977 (w), 2940 (w), 1709 (s), 1464 (m), 1413 (m), 1111 (m), 837 (s), 826 (m), 754 (s), 678 (m). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.10 (t, J = 7.3 Hz, 3 H, 5′-H), 2.45 (d, J = 7.3 Hz, 2 H, 4′-H), 2.95 (t, J = 8.2 Hz, 1 H, 2′-H), 4.02 (t, J = 8.3 Hz, 1 H, 1′-H), 7.80−7.82 (m, 2 H, 8-H, 9-H), 7.93 (d, J = 9.3 Hz, 1 H, 12-H), 7.94 (“t”, J = 7.5 Hz, 1 H, 2-H), 8.04 (“d”, J = 7.5 Hz, 1 H, 1-H), 8.18 (“d”, J = 7.5 Hz, 1 H, 3-H), 8.22 (d, J = 9.0 Hz, 1 H, 4-H), 8.24 (d, J = 9.0 Hz, 1 H, 5-H), 8.46−8.48 (m, 1 H, 7-H), 9.01 (d, J = 9.5 Hz, 1 H, 11-H), 9.07−9.09 (m, 1 H, 10-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 17.9 (q, C-5′), 22.3 (t, C-1′), 36.2 (t, C-4′), 43.3 (t, C-2′), 122.1 (d, C-11), 123.8 (d, C-10), 123.8 (s, C-12c), 124.0 (d, C-5), 124.5 (d, C-7), 124.8 (d, C-1), 125.5 (s, C-12b), 125.7 (d, C-9) 125.7 (d, C-3), 126.2 (d, C-2), 126.4 (d, C-8), 126.6 (s, C-5a), 127.1 (d, C-4), 127.1 (s, C-10b), 128.2 (s, C-10a), 128.3 (d, C-12), 129.5 (s, C-6a), 131.2 (s, C-3a), 131.6 (s, C-12a), 131.8 (s, C-6), 210.7 (s, C-3′) ppm. MS (EI): *m*/*z* (%) = 336 (74) [M$^+$], 276 (12), 265 (100), 252 (6), 250 (5), 239 (5).

By-product 14: R_f = 0.58. IR (KBr): ṽ = 3045 cm^{-1} (w), 3045 (w), 2926 (w), 1713 (vs), 1678 (s), 1459 (w), 1416 (w), 1123 (m), 839 (s), 827 (m), 760 (s), 691 (m). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.86 (s, 3 H, 1′-H), 2.97 (ddd, J = 18.1 Hz, 11.8, 6.5, 2 H, 3′-H), 6.60 (ddd, J = 18.8 Hz, 11.4, 11.8, 1 H, 4′-H), 7.35 (d, J = 11.4 Hz, 1 H, 5′-H), 7.77 (“t”, 1 H, 8-H), 7.84 (“t”, 1 H, 9-H), 7.90 (d, J = 9.3 Hz, 1 H, 12-H), 7.97 (“t”, J = 7.5 Hz, 1 H, 2-H), 8.07 (“d”, J = 7.5 Hz, 1 H, 1-H), 8.11 (d, J = 9.0 Hz, 1 H, 5-H), 8.23 (“d”, J = 7.5 Hz, 1 H, 3-H), 8.31 (d, J = 9.0 Hz, 1 H, 4-H), 8.42 (“d”, 1 H, 7-H), 9.06 (d, J = 9.3 Hz, 1 H, 11-H), 9.09 (“d”, 1 H, 10-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): 30.0 (q, C-1′), 43.6 (t, C-3′), 122.1 (d, C-11), 123.3 (d, C-10), 123.5 (s, C-12c), 125.1 (d, C-1), 125.5 (s, C-12b), 125.9 (d, C-3), 125.9 (d, C-9), 126.0 (d, C-5), 126.2 (d, C-8), 126.3 (d, C-2), 126.6 (d, C-7), 127.1 (s, C-5a), 127.1 (s, C-10b), 127.6 (d, C-4), 128.0 (s, C-10a), 128.2 (d, C-12), 128.5 (d, C-4′), 129.3 (d, C-5′), 129.5 (s, C-6), 129.6 (s, C-6a), 131.3 (s, C-3a), 131.6 (s, C-12a), 206.4 (s, C-2′) ppm. MS (EI): *m*/*z* (%) = 334 (11) [M$^+$], 289 (17), 276 (28), 149 (100), 43 (48).

3-(Benzo[*a*]pyren-6-yl)propanoic Acid (6): NaOH (585 mg) was dissolved with stirring in water (3.3 mL), and bromine (184 μL) was added dropwise at 0 °C. Two thirds of this freshly prepared hypobromide solution were added dropwise at room temperature to a solution of methyl ketone **4a** (200 mg, 0.57 mmol), and after the mixture had been stirred for 3 h the rest of the hypobromide solution (stored at 0 °C) was added and stirring was continued for a further 3 h. The reaction mixer was poured into toluene (100 mL) and neutralized with HCl. The organic layer was separated in a dropping funnel and washed with water (30 mL) and brine (30 mL). After the solution had been dried with $MgSO_4$, the solvents were distilled off and the crude acid was purified by chromatography (silica, MTBE/PE). Yield: 103 mg (0.32 mmol, 56%) of **6**, which was recrystallized from heptane for an analytical sample. R_f = 0.35 (silica, MTBE/PE). IR (KBr): ṽ = 3037 cm−1 (w), 2974 (w), 2915 (w), 1708 (s), 1464 (m), 1164 (m), 836 (m), 834 (m), 755 (s), 692 (m). 1H NMR (400 MHz, [D$_6$]DMSO): δ = 2.73 (t, J = 8.3 Hz, 2 H, 2′-H), 4.02 (t, J = 8.3 Hz, 2 H, 3′-H), 7.87−7.92 (m, 2 H, 8-H, 9-H), 8.03 (“t”, J = 7.5 Hz, 1 H, 2-H), 8.07 (d, J = 9.3 Hz, 1 H, 12-H), 8.18 (“d”, J = 7.5 Hz, 1 H, 1-H), 8.31 (“d”, J = 7.5 Hz, 1 H, 3-H), 8.37 (d, J = 9.0 Hz, 1 H, 4-H), 8.38 (d, J = 9.0 Hz, 1 H, 5-H), 8.61 (“d”, J = 7.5 Hz, 1 H, 7-H), 9.19 (d, J = 9.3 Hz, 1 H, 11-H), 9.24 (“d”, J = 9.0 Hz, 1 H, 10-H), 12.35 (s, 1 H, COOH) ppm. 13C NMR (100 MHz, [D$_6$]DMSO): δ = 23.2 (t, C-3′), 35.3 (t, C-2′), 122.3 (d, C-11), 122.8 (s, C-12c), 123.9 (d, C-10), 124.5 (d, C-5), 124.5 (s, C-12b), 124.6 (d, C-7), 124.8 (d, C-1), 125.7 (d, C-3), 126.0 (d, C-9), 126.1 (s, C-5a), 126.4 (d, C-2), 126.6

(s, C-10b), 126.8 (d, C-8), 127.2 (d, C-4), 127.7 (s, C-10a), 128.2 (d, C-12), 129.1 (s, C-6a), 130.6 (s, C-3a), 131.0 (s, C-12a), 131.6 (s, C-6), 173.7 (s, C-1′) ppm. MS (EI): *m*/*z* (%) = 324 (47) [M+], 276 (13), 265 (100), 251 (3), 250 (5), 239 (6).

4-(Benzo[*a*]pyren-6-yl)butanoic Acid (7): Water (1 mL) and KOH (1.2 g, 23 mmol) were added to a well degassed solution of **5a** (400 mg, 0.91 mmol) in 2-methoxyethylene glycol (50 mL) and the mixture was heated at reflux under argon for 6 h. Toluene (200 mL) was added, and the organic layer was extracted first with half concentrated Na_2CO_3 solution (50 mL) and then twice with concentrated Na_2CO_3 solution (50 mL). The combined aqueous layers were acidified to pH 2 with HCl and then extracted three times with toluene (50 mL). The toluene phases were washed with brine (50 mL) and dried with $MgSO_4$, and the solvents were evaporated to dryness. Chromatography (silica, ethyl acetate/petroleum ether, 1:3) yielded the acid **7** (120 mg, 0.35 mmol, 39%) as a yellow/grey powder. R_f = 0.23. IR (KBr): $\tilde{\nu}$ = 3038 cm^{-1} (m), 2965 (m) 1698 (s), 1407 (m), 837 (m), 826 (m), 757 (s), 692 (m). ^1H NMR (400 MHz, [D_6]DMSO): δ = 2.05 (tt, *J* = 8.2 Hz, 7.0, 2 H 3′-H), 2.58 (t, *J* = 7.0 Hz, 2 H, 2′-H), 3.78 (t, *J* = 8.2 Hz, 2 H, 4′-H), 7.90 ("dd", *J* = 6.5, 3.0 Hz, 2 H, 8-H, 9-H), 8.04 ("t", *J* = 7.4 Hz, 1 H, 2-H), 8.08 (d, *J* = 9.3 Hz, 1 H, 12-H), 8.19 ("d", *J* = 7.4 Hz, 1 H, 1-H), 8.33 ("d", *J* = 7.4 Hz, 1 H, 3-H), 8.39 (d, *J* = 9.5 Hz, 1 H, 4-H), 8.46 (d, *J* = 9.5 Hz, 1 H, 5-H), 8.72 ("dd", *J* = 6.5, 3.0 Hz, 1 H, 7-H), 9.23 (d, *J* = 9.3 Hz, 1 H, 11-H), 9.27 ("dd", *J* = 6.5, 3.0 Hz, 1 H, 10-H), 12.17 (s, 1 H, COOH) ppm. ^{13}C NMR (100 MHz, [D_6]DMSO): δ = 26.3 (t, C-3′), 27.1 (t, C-4′), 33.5 (t, C-2′), 122.4 (d, C-11), 122.9 (s, C-12c), 123.8 (d, C-10), 124.4 (d, C-5), 124.6 (s, C-12b), 124.7 (d, C-7), 124.9 (d, C-1), 125.6 (d, C-3), 125.9 (s, C-5a), 126.0 (d, C-9), 126.3 (d, C-2), 126.6 (s, C-10b), 126.6 (d, C-8), 127.0 (d, C-4), 127.7 (s, C-10a), 127.9 (d, C-12), 129.4 (s, C-6a), 130.7 (s, C-3a), 131.1 (s, C-12a), 133.0 (s, C-6), 174.5 (s, C-1′) ppm. MS (EI): *m*/*z* (%) = 338 (38) [M^+], 276 (9), 265 (100), 251 (3), 250 (3), 239 (4).

5-(Benzo[*a*]pyren-6-yl)pentanoic Acid (8): The acid **8** (55 mg, 0.16 mmol, 58%) was obtained by use of the same procedure as described for **7**, starting from compound **5b** (120 mg, 0.27 mmol) with KOH (350 mg, 6.1 mmol) in 2-methoxyethylene glycol (30 mL). R_f = 0.20 (silica, ethyl acetate/petroleum ether, 1:1). IR (KBr): $\tilde{\nu}$ = 3452 cm^{-1} (s), 3036 (m), 2927 (m) 1707 (vs), 1407 (m), 837 (s), 824 (m), 755 (s), 691 (m). ^1H NMR (400 MHz, $(CD_3)_2CO$]: δ = 1.98−2.00 (m, 4 H, 4′-H, 3′-H), 2.47 (t, *J* = 6.5 Hz, 2 H, 2′-H), 3.85 (t, *J* = 7.3 Hz, 2 H, 4′-H), 7.87 ("dd", *J* = 7.2 Hz, 3.0, 2 H, 8-H, 9-H), 8.00 ("t", *J* = 7.5 Hz, 1 H, 2-H), 8.04 (d, *J* = 9.5 Hz, 1 H, 12-H), 8.15 ("d", *J* = 7.5 Hz, 1 H, 1-H), 8.28 ("d", *J* = 7.5 Hz, 1 H, 3-H), 8.35 (d, *J* = 9.3 Hz, 1 H, 4-H), 8.43 (d, *J* = 9.3 Hz, 1 H, 5-H), 8.69 ("dd", *J* = 7.2 Hz, 3.0, 1 H, 7-H), 9.18 (d, *J* = 9.0 Hz, 1 H, 11-H), 9.23 ("dd", *J* = 7.2 Hz, 3.0, 1 H, 10-H), 10.50 (s, 1 H, COOH) ppm. ^{13}C NMR (100 MHz, $(CD_3)_2CO$]: δ = 26.2 (t, C-3′), 28.7 (t, C-5′), 31.8 (t, C-4′), 34.2 (t, C-2′), 123.3 (d, C-11), 124.7 (s, C-12c), 124.7 (d, C-10), 125.6 (d, C-5), 125.7 (d, C-1), 126.1 (d, C-7), 126.4 (s, C-12b), 126.6 (d, C-3), 126.8 (d, C-9), 127.3 (d, C-2), 127.4 (s, C-5a), 127.4 (d, C-8), 128.0 (s, C-10b), 128.0 (d, C-4), 129.0 (d, C-12), 129.4 (s, C-10a), 130.9 (s, C-6a), 132.4 (s, C-3a), 132.8 (s, C-12a), 134.6 (s, C-6), 174.7 (s, C-1′) ppm. MS (EI): *m*/*z* (%) = 352 (38) [M^+], 323 (<2), 289 (<2), 265 (100), 252 (3), 239 (4).

5-(1,3-Dibromobenzo[*a*]pyren-6-yl)pentan-2-one (10): Ketone **4b** (60 mg, 0.18 mmol) in dry THF (8 mL) and dry dioxane (8 mL) was added at 0 °C to a stirred solution of KOH (100 mg, 1.8 mmol) and bromine (280 μL, 0.54 mmol) in water (0.5 mL). The solution was stirred at room temperature for 1 h and the precipitate was then filtered off and washed with a little water and MTBE. Yield: 64 mg (0.13 mmol, 71%) of the dibromo compound **10**. IR (KBr): $\tilde{\nu}$ = 3073 cm^{-1} (w), 2928 (w), 2892 (w), 1715 (vs), 1593 (w), 1479 (m), 900 (s), 813 (s), 752 (s), 652 (m). ^1H NMR (400 MHz, $CDCl_3$): δ = 2.14−2.21 (m, 2 H, 4′-H), 2.20 (s, 3 H, 1′-H), 2.69 ("t", *J* = 6.8 Hz, 2 H, 3′-H), 3.73−3.77 (m, 2 H, 5′-H), 7.85−7.90 (m, 2 H, 8-H, 9-H), 8.27 (d, *J* = 9.8 Hz, 1 H, 5-H), 8.46 (s, 1 H, 2-H), 8.47 (d, *J* = 9.8 Hz, 1 H, 4-H), 8.57 (d, *J* = 9.5 Hz, 1 H, 12-H), 8.62−8.65 (m, 1 H, 7-H), 9.08−9.10 (m, 1 H, 10-H), 9.13 (d, *J* = 9.5 Hz, 1 H, 11-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 25.1 (t, C-4′), 27.8 (t, C-5′), 30.2 (q, C-1′), 43.1 (t, C-3′), 118.9 (s, C-3), 119.9 (s, C-1), 122.7 (s, C-12c), 123.7 (d, C-11), 123.8 (d, C-10), 125.1 (d, C-7), 125.5 (d, C-12), 126.0 (d, C-4), 126.3 (d, C-5), 126.4 (d, C-9), 126.8 (s, C-12b), 126.9 (s, C-10b), 127.1 (d, C-8), 127.5 (s, C-6a), 128.5 (s, C-5a), 129.3 (s, C-10a), 129.4 (s, C-12a), 130.4 (s, C-3a), 133.5 (d, C-2), 134.7 (s, C-6), 208.4 (s, C-2′) ppm. MS (EI): *m*/*z* (%) = 495 (65) [M^+], 436 (20), 423 (100), 344 (8), 263 (92), 251 (4), 43 (25).

***tert*-Butyl 4-(Benzo[*a*]pyren-6-yl)-2-methylbutanoate (11):** The ketone **4b** (140 mg), potassium *tert*-butoxide (470 mg, 4.2 mmol) and iodine (210 mg, 0.84 mmol) were dissolved in dry *tert*-butyl alcohol (80 mL) in a screw-cap vessel, and heated to 90 °C under argon for 2 h. The solvent was distilled off and the residue was redissolved in toluene (100 mL). After having been washed with Na_2SO_3 solution (40 mL), water (50 mL) and brine the solution was dried with $MgSO_4$. Evaporation of the solvent and chromatography (silica, ethyl acetate/petroleum ether, 1:2) yielded the ester **11** (65 mg, 0.16 mmol). R_f = 0.35. IR (KBr): $\tilde{\nu}$ = 3040 cm^{-1} (w), 2974 (w), 2941 (w), 1715 (vs), 1515 (w), 1491 (w), 1228 (w), 837 (m), 824v (m), 756 (s), 692 (m). ^1H NMR (400 MHz, $CDCl_3$): δ = 1.31 (d, *J* = 7.0 Hz, 3 H, Me) 1.60 (s, 9 H, *t*Bu), 1.92−2.01 (m, 1 H, 3_a′-H), 2.17−2.27 (m, 1 H, 3_b′-H), 2.68−2.72 (m, 1 H, 2′-H), 3.69−3.82 (m, 2 H, 4′-H), 7.81−7.83 (m, 2 H, 8-H, 9-H), 7.94 (dd, *J* = 7.9, 7.5 Hz, 1 H, 2-H), 7.95 (d, *J* = 9.3 Hz, 1 H, 12-H), 8.06 (dd, *J* = 7.5, 1.0 Hz, 1 H, 1-H), 8.19 (d, *J* = 7.9, 1.0 Hz, 1 H, 3-H), 8.25 (d, *J* = 9.3 Hz, 1 H, 4-H), 8.30 (d, *J* = 9.3 Hz, 1 H, 5-H), 8.56−8.59 (m, 1 H, 7-H), 9.03 (d, *J* = 9.3 Hz, 1 H, 11-H), 9.09−9.10 (m, 1 H, 10-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 17.8 (q, Me), 26.5 (t, C-4′), 28.4 (q, *t*Bu), 35.3 (t, C-3′), 41.4 (t, C-2′), 80.5 (s, *t*Bu), 122.3 (d, C-11), 123.8 (d, C-10), 124.0 (s, C-12c), 124.5 (d, C-5), 124.7 (d, C-1), 125.0 (d, C-7), 125.6 (s, C-12b), 125.7 (2d, C-3,C-9), 126.1 (d, C-8), 126.4 (d, C-2), 126.6 (s, C-5a), 127.0 (d, C-4), 127.2 (s, C-10b), 128.2 (d, C-12), 128.4 (s, C-10a), 129.9 (s, C-6a), 131.4 (s, C-3a), 131.7 (s, C-12a), 133.0 (s, C-6), 176.1 (s, C-1′) ppm. MS (EI): *m*/*z* (%) = 307 (2), 286 (36), 265 (10), 252 (100), 250 (28), 125 (18).

4-(Pyren-1-yl)pentan-2-one (16): The ketone **16** (180 mg, 0.63 mmol, 63%) was obtained by the same procedure as described for **4**, starting from the iodide **15** (330 mg, 1.0 mmol). R_f = 0.33 (silica, MTBE/petroleum ether, 1:2). IR (KBr): $\tilde{\nu}$ = 2948 cm^{-1} (m), 2886 (m), 1711 (vs), 1601 (m), 1159 (m), 840 (m), 763 (m), 708 (m). ^1H NMR (400 MHz, $CDCl_3$): δ = 2.11−2.18 (m, 2 H, 4′-H), 2.12 (s, 3 H, 1′-H), 2.54 (t, *J* = 7.2 Hz, 2 H, 3′-H), 3.35 (t, *J* = 7.7 Hz, 2 H, 5′-H), 7.83 (d, *J* = 7.8 Hz, 1 H, 2-H), 7.98 (dd, *J* = 7.8 Hz, 7.5, 1 H, 7-H), 8.02 (2d, *J* = 9.0 Hz, 2 H, 4-H, 5-H), 8.10 (d, *J* = 7.8 Hz, 1 H, 3-H), 8.11 (d, *J* = 9.3 Hz, 1 H, 9-H), 8.15 (dd, *J* = 7.8, 1.1 Hz, 1 H, 8-H), 8.16 (dd, *J* = 7.5, 1.1 Hz, 1 H, 6-H), 8.30 (d, *J* = 9.3 Hz, 1 H, 10-H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 25.7 (t, C-4′), 30.2 (q, C-1′), 32.8 (t, C-5′), 43.2 (t, C-3′), 123.6 (d, C-10), 125.0 (2d, C-6,C-8), 125.1 (d, C-3), 125.2 (s, C-10b), 125.3 (s, C-10c), 126.0 (d, C-7), 126.9 (d C-5/C-4), 127.5 (d, C-2), 127.6 (d, C-9), 127.7 (d, C-5/C-4), 129.0 (s, C-10a), 130.2 (s, C-3a),

131.1 (s, C-8a), 131.6 (s, C-5a) 136.1 (s, C-1), 208.8 (s, C-2′) ppm. MS (EI): *m*/*z* (%) =286 (61) [M^+], 228 (74), 215 (100), 202 (7), 43 (43). $C_{21}H_{18}O$ (286.14 g/mol)·1.5 H_2O: calcd. C 86.98, H 6.40 found C 86.95, H 6.12.

4-(Pyren-6-yl)butanoic Acid (7): The acid **17** (64 mg, 0.22 mmol, 79%) was obtained by the same procedure as described for **6**, starting from the ketone **16** (80 mg, 0.20 mmol). R_f = 0.28 (silica, MTBE/petroleum ether, 1:1). IR (KBr): $\tilde{\nu}$ = 2929 cm^{-1} (w), 1607 (m), 1451 (s), 1073 (m,) 988 (m), 878 (w), 834 (w). ^1H NMR (400 MHz, [D_6]DMSO): δ = 1.97−2.04 (m, 2 H, 3′-H), 2.38 (t, *J* = 7.3 Hz, 2 H, 2′-H), 3.34 (dd, *J* = 8.7, 6.9 Hz, 2 H, 4′-H), 7.93 (d, *J* = 7.8 Hz, 1 H, 2-H), 8.05 (dd, *J* = 7.8, 7.5 Hz, 1 H, 7-H), 8.12 (2d, *J* = 8.9 Hz, 2 H, 4-H, 5-H), 8.20 (d, *J* = 9.4 Hz, 1 H, 9-H), 8.22 (d, *J* = 7.8 Hz, 1 H, 3-H), 8.24 (dd, *J* = 7.5, 1.3 Hz, 2 H, 8-H), 8.27 (dd, *J* = 7.8, 1.3 Hz, 2 H, 6-H), 8.39 (d, *J* = 9.4 Hz, 1 H, 10-H) ppm. ^{13}C NMR (100 MHz, [D_6]DMSO): δ = 26.8 (t, C-3′), 31.9 (q, C-2′), 33.3 (t, C-4′), 123.4 (d, C-10), 124.1 (s, C-10b), 124.2 (s, C-10c), 124.7 (d, C-3), 124.9 (2d, C-6,C-8), 126.1 (d, C-7), 126.5 (d, C-4/C-5), 127.2 (d, C-2), 127.4 (d, C-9), 127.4 (d, C-5/C-4), 128.1 (s, C-10a), 129.3 (s, C-3a), 130.4 (s, C-8a), 130.8 (s, C-5a), 136.3 (s, C-1), 174.3 (s, C-1′).

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