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Preparation of *cis*-5-Methoxy-and-7-Methoxy-1-Acetoxy-1,2,3,4,4a,10a-Hexahydro-9(10*H*)-Phenanthrenone. An Epoxide-Arene Reaction Involving a Selective 1,2-Alkyl Shift Rearrangement.

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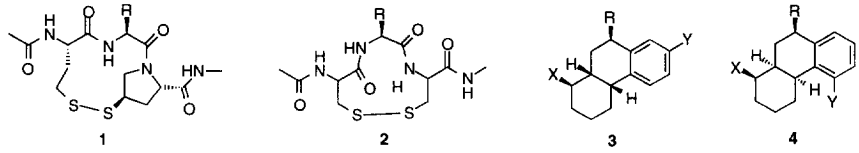
Abstract: The preparation of cis-1α-acetoxy-7-methoxy-1,2,3,4,4a,10a-hexahydro-9(10H)-phenanthrenone **5** was accomplished starting from 6-methoxy-1-tetralone. Reduction of 7-methoxy-1,2,3,4,9,10-hexahydro-1-oxo-phenanthrene **8**, acetylation and subsequent oxidation delivered **5**. Application of an analogus procedure to the preparation of cis-1β-acetoxy-5-methoxy-1,2,3,4,4a,10a-hexahydro-9(10H)-phenanthrenone **6** was not feasible. A more elaborate route was developed for the synthesis of compound **6**, where an epoxide-arene reaction involving a 1,2-alkyl shift rearrangement, constituted a highly selective key transformation. Copyright © 1996 Elsevier Science Ltd

INTRODUCTION

Disulfide cyclization is a powerful method of reducing the conformational space of a peptide. This method enables the study of peptide bioactive conformations and may provide a starting point for conversion of peptides to compounds with less peptidic character. Recently Marshall *et al.* demonstrated the effects of side-chain cyclization between residues i and i+2, in different tripeptides, on restriction of the allowed backbone conformation.[1,2] Cyclization of peptides with *trans*-4-mercaptoproline (MPt) and *cis*-4-mercaptoproline at one position, and Cys or Hcy (homocysteine) at the other position provided a new route to highly constrained bicyclic analogues. Particularly interesting was the cyclic tripeptide fragment Hcy-Tyr-Mpt which when incorporated in to the 3-5 position of the blood pressure regulating hormone angiotensin II (AngII) afforded an agonist almost equally potent to the native peptide.[2]

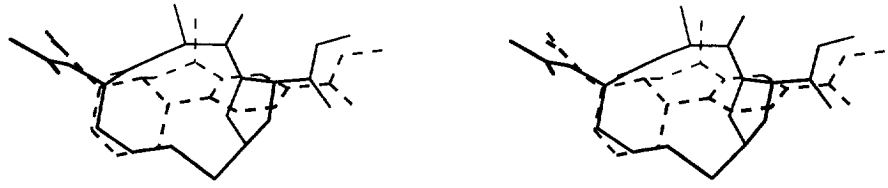
The conformational space for the disulfide bridged tripeptide Cys-Ala-Cys was also found to be restricted.[1] Theoretical calculations[3,4] and NMR-spectroscopy[4] suggest that the Cys-Tyr-Cys moiety preferentially adopts an inverse γ-turn conformation. This tripeptide fragment which has also been incorporated into the 3-5 position of AngII afforded a ligand with high affinity but no contractile activity.[5]



1 2 3 4

We have an interest in the preparation of secondary structure mimetics and were encouraged to synthesize rigid non-peptidergic structures mimicking the Hcy-aa-Mpt fragment **1** and the Cys-aa-Cys fragment **2**, where aa is an amino acid residue. Molecular modelling and conformational analyses[6] using MacroModel[7] (version 4.5) suggested that the tricyclic compound **3** and **4** should provide proper scaffolds for these tripeptide units (Figure 1).

a)



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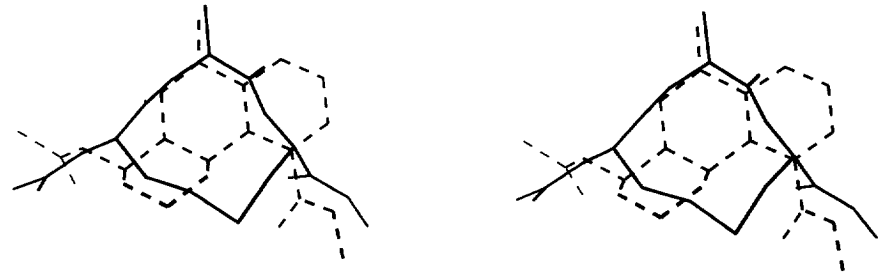
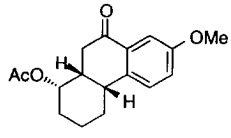
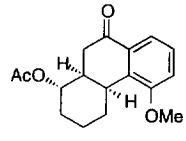


Figure 1. Stereoview showing the fit of (a) **1** (solid lines) and **3** (dashed lines) and (b) **2** (solid lines) and **4** (dashed lines) in their lowest energy conformation as identified by the Monte Carlo search. For clarity, the hydrogens have been omitted from the picture.

We desired common synthetic intermediates that both allowed for flexible conversion into a mimetic of a specific peptide unit (e.g. X=NH_2, Y=COOH and R=p-$CH_2C_6H_4OH$) and into mimetics of their D-amino acid counterparts. We selected the tricyclic compounds **5** and **6** as suitable precursors for **3** and **4** and here report the non enantioselective synthesis of **5** and **6**. Two entirely different synthetic approaches were used for the construction of the common carbon skeleton of the two regioisomers. The synthesis of **6** relied on an epoxy-arene cyclization involving a highly selective 1,2-alkyl rearrangement from a phenonium ion.



5

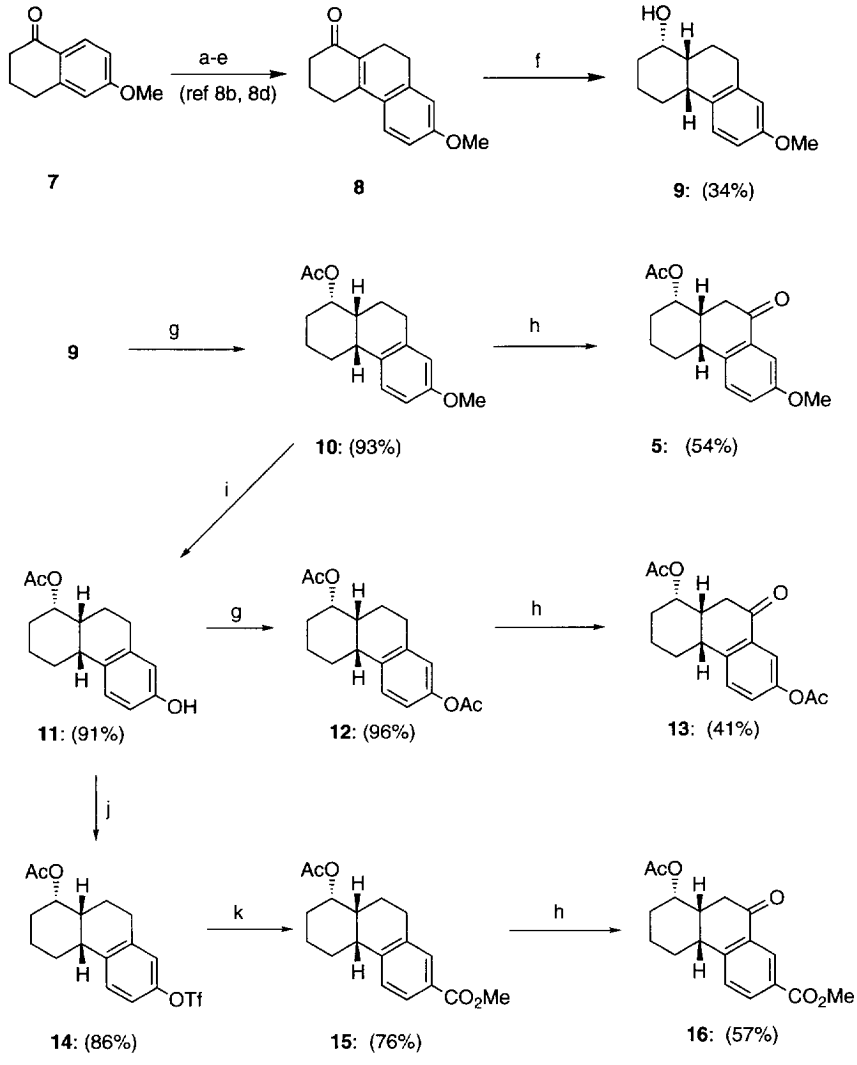


6

RESULTS AND DISCUSSION

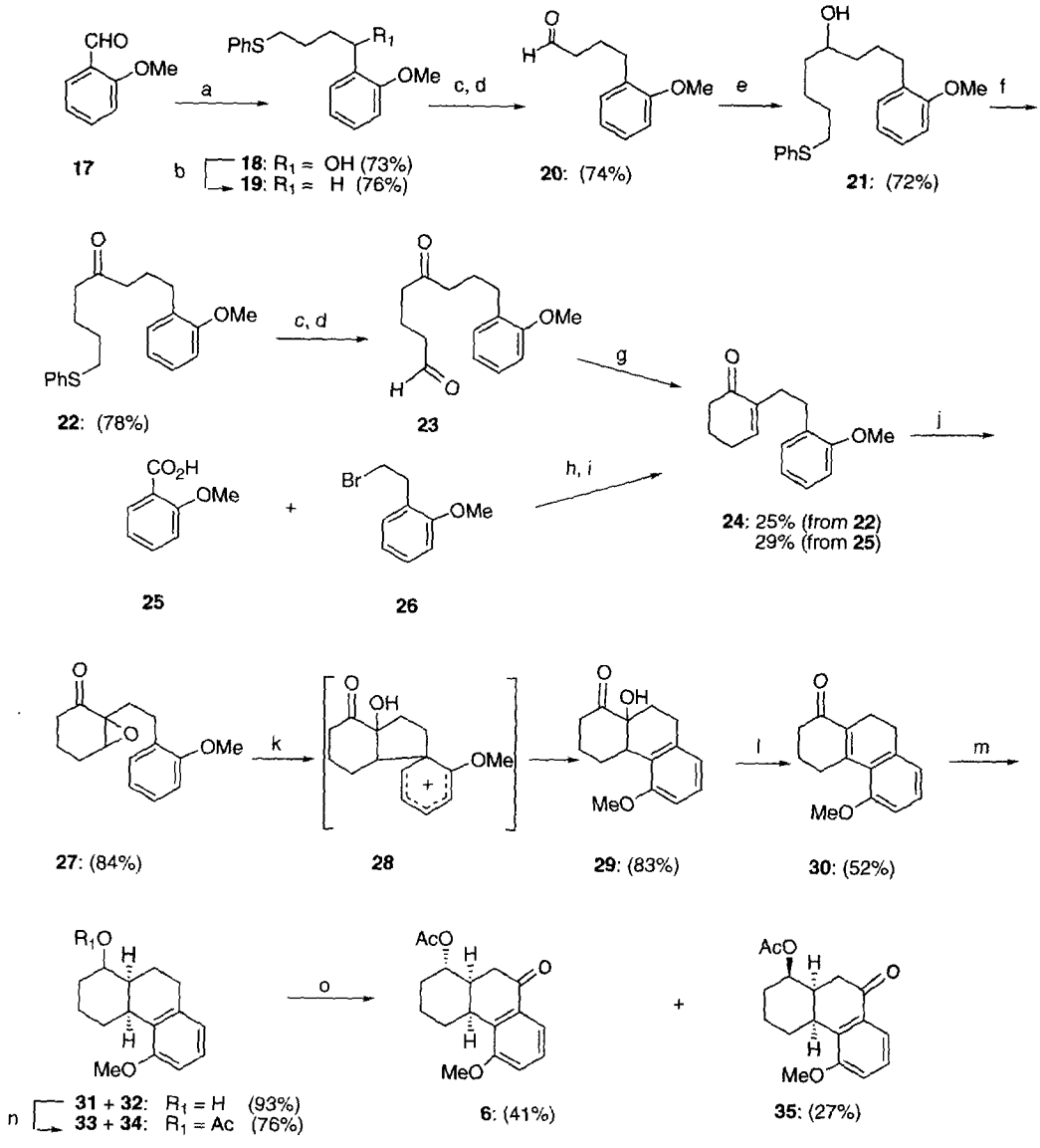
For the preparation of **5** we used the tricyclic unsaturated ketone **8** as a key intermediate[8a-h] (scheme 1). We synthesised **8** in an over all yield of 38% from commercially available 6-methoxy-1-tetralone **7**, following the reaction sequence reported by Stork[8b] and which was later modified by Nagata.[8d] Subsequent hydrogenation[9a,9b] of **8** on Pd/C at a pressure of one atmosphere in ethyl acetate furnished the desired *cis*-diasterioisomer **9** in 34% yield. No *trans*-diastereomers were formed according to a NMR analysis of the crude product. Alternative reductive methods producing mixture of diastereomers are available.[10a-p] Acetylation of the hydroxyl group in **9** and subsequent oxidation[11] with 3,5-DMP and chromium trioxide in dichloromethane led to the target compound **5** in 54% yield. The same oxidative conditions[11] permitted conversion of **12** to the ketone **13** in 41% yield. The benzylic oxidation[11] also occurred smoothly when the carbomethoxy derivative **15** was subjected to the reaction conditions, and **16**, a conceivable alternative precursor for **3**, was isolated. The conversion of the methoxy derivative **10** to the corresponding carbomethoxy compound **15** was achieved by ether cleavage and palladium-catalysed carbonylation of the triflate **14** (scheme 1).

We planned to prepare **6** from the unsaturated tricyclic ketone **30** essentially following the reaction sequence discussed above. No synthetic route to the isomer **30** had been described previously and 8-methoxy-1-tetralone is not commercially available. We assumed that **24** should provide a suitable key intermediate for synthesis of **30**.[12a-h] Two synthetic routes[12c,12e] to the 2-methoxy intermediate **24** were explored (scheme 2). We first applied a recently reported reaction sequence used by Hauser[12e] to the synthesis of a closely related analogue; compound **24**, substituted in the aromatic ring with a methyl group in the *para*-position to the alkyl chain. Thus, reaction of 2-methoxybenzaldehyde with the Grignard reagent derived from 1-bromo-3-(phenylthio)propane in THF furnished the hydroxy sulfide **18** in 73% yield. Reductive removal of the hydroxyl group and subsequent oxidative conversion of the phenylthio group provided the aldehyde **20**. A second Grignard reaction followed by two oxidative steps furnished a keto aldehyde that smoothly cyclized and underwent dehydration to give **24**.



Reagents and conditions: (a) Zn, $HgCl_2$, methyl γ-bromocrotonate, benzene-diethyl ether; (b) Raney-Ni, dioxane, H_2 (1 atm.); (c) $KHCO_3$, MeOH-H_2O; (d) $ZnCl_2$, AcOH, Ac_2O (e) NaOH, MeOH-H_2O; (f) Pd-C, ethyl acetate, H_2 (1 atm.); (g) Ac_2O, DMAP, CH_2Cl_2; (h) 3, 5-DMP-CrO_3, CH_2Cl_2; (i) BBr_3, CH_2Cl_2; (j) N-Phenyl-trifluoromethanesulfonimide, Et_3N, CH_2Cl_2; (k) $Pd(OAc)_2$, DPPP, Et_3N, MeOH, DMF, CO (2.5 atm.).

Scheme 1



Reagents and conditions: (a) $PhS(CH_2)_3Br$, Mg, THF; (b) $AlCl_3$, LAH, ether; (c) NCS, CCl_4; (d) CuO, $CuCl_2$, acetone-H_2O; (e) $PhS(CH_2)_4Br$, Mg, THF; (f) PCC-Celite, CH_2Cl_2; (g) $HClO_4$-THF-H_2O; (h) Na-NH_3, THF; (i) hydroquinone, 1,2-dichloroethane, HCl-H_2O; (j) H_2O_2, NaOH, MeOH-H_2O; (k) $SnCl_4$, CH_2Cl_2; (l) PPA ; (m) Raney Ni, 2N NaOH, ethanol, H_2 (1 atmp); (n) Ac_2O, DMAP, CH_2Cl_2; (o) 3,5-DMP-CrO_3, CH_2Cl_2.

Scheme 2

The Taber reaction[12c] provided a considerably more convenient route to **24**. Reaction of 2-methoxybenzoic acid **25** with sodium in ammonia and subsequent addition of 2-methoxyphenethyl bromide **26** and acidic treatment gave a 29% yield of **24**. Epoxidation[12f] of **24** followed by stannic chloride mediated epoxide cyclialkylation[13] to give **29** and subsequent dehydration provided **30**. Attempted cyclization of **24** by treatment with Lewis acid[12e] produced a complex mixture.

The structure of **29** was established by NMR (see experimental section) and by X-ray crystallography[13] (figure 2). Taylor has studied Friedel-Craft cyclization extensively.[14a,14b] It was reported that 1,2-epoxy-5-(*m*-methoxyphenyl) pentane produced a mixture of compounds derived from *ortho*- and *para*-substitution and accordingly we expected a similar mixture to be formed from a *meta*-methoxy derivative in our system. However, an analysis of Dreiding models suggested that a nucleophilic attack at the epoxide by the *ipso*-carbon *ortho* to the methoxy group in **27** should be favoured. An *ipso*-carbon attack and subsequent 1,2-alkyl shift of the primary alkyl chain occurred exclusively and no derivative associated with migration of the ring system from a postulated charged spiro intermediate **28** was observed.

Hydrogenation[9a] of **30** on Raney Ni at one atmosphere in ethanol gave a mixture of **31** and **32** (difficult to separate) in 93% yield, which was acetylated to give a mixture of **33** and **34** in 76% yield. Oxidation[11] of the mixture of **33** and **34** with 3,5-DMP and chromium trioxide in dichloromethane delivered target compounds **6** and **35** in 41% and 27% yield respectively after chromatographic separation (Scheme 2).

We conclude that **5** and **6**, two potential precursors of the cyclic tripeptide mimetics **3** and **4**, can be prepared from the corresponding tricyclic ketones **8** and **30**, respectively. While the key intermediate **8** was synthesised conveniently according to a literature procedure, a more elaborate reaction sequence was required to obtain the ketone **30**. The latter compound was prepared by a highly selective 1,2 alkyl rearrangement from an intermediate phenonium ion.

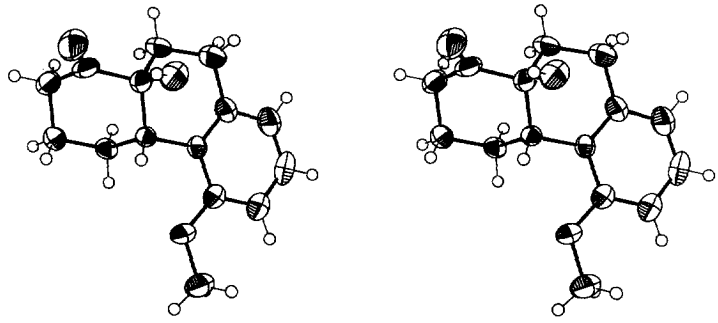


Figure 2. X-ray Diffraction Structure of **29**.

EXPERIMENTAL SECTION

Melting points were determined on a Thomas-Hoover capillary melting point apparatus and are uncorrected. NMR spectra were recorded for ^1H at 270 MHz and 400 MHz, for ^{13}C at 67.8 MHz, on a Jeol JNM-EX-270 or a Varian Unity 400 instrument. Chemical shifts are indirectly referenced to TMS by the solvent signal ($CDCl_3$: 7.26 and 77.0). Signal assignments were made from homonuclear and hetronuclear correlated spectra. NOEs were detected by NOE difference spectra or NOSEY spectra. TLC was carried out using Merck pre-coated silica gel $60F_{254}$ plates in 15-50% diethyl ether in hexane; the spot were detected with UV light. Column chromatography was carried out using Merck G60 silica gel and gradient elution with diethyl ether and hexane. The elemental analyses were performed by MikroKemi AB, Uppsala, Sweden. A Jeol SX102 instrument was used for recording mass spectra. THF and diethyl ether were dried and distilled from sodium and benzophenone. Dichloromethane was dried over $MgSO_4$. All other commercial chemicals were used without further purification.

***cis*-1α-Hydroxy-7-methoxy-1, 2, 3, 4, 4a, 9, 10, 10a-octahydrophenanthrene (9)**: A solution of **8** (3.6 g, 15.8 mmol) in ethyl acetate (60 ml) containing 5% Pd-C (160 mg) was stirred under hydrogen (1 atmosphere) at room temperature for 16 h, then filtered through a short pad of celite. The solids were washed with ethyl acetate (50 ml), and the combined filtrates evaporated at reduced pressure. The residue was purified on a silica gel column to give **9** (1.23 g, 34%), (m.p 86-88 °C, crystallised from a mixture of diethyl ether and hexane). ^1H-NMR ($CDCl_3$): 6.99 (d, 1H) Ar; 6.68 (dd, J = 2.6 Hz, 8.6 Hz, 1H) Ar; 6.62 (d, 1H) Ar; 3.89 (m, 1H) H-1; 3.77 (s, 3H) OMe; 2.92-2.66 (m, 3H) H-9, H-4_a; 2.25-2.17 (m, 1H) H-10_a; 1.97-1.34 (m, 9H) H-2, H-3, H-4, H-10, OH. ^{13}C-NMR ($CDCl_3$): 157.3 (s) Ar; 137.4 (s) Ar; 133.6 (s) Ar; 129.8 (d) Ar; 113.2 (d) Ar; 111.9 (d) Ar; 72.5 (d) C-1; 55.1 (q) OMe; 40.8 (d) C-10_a; 39.6 (d) C-4_a; 30.9 (t) CH_2; 29.7 (t) C-9; 29.1 (t) CH_2; 24.1 (t) CH_2; 15.8 (t) C-10. Anal. calcd. for $C_{15}H_{20}O_2$: C, 77.6; H, 8.6. Found: C, 77.6; H, 8.6.

***cis*-1α-Acetoxy-7-methoxy-1, 2, 3, 4, 4a, 9, 10, 10a-octahydrophenanthrene (10)**: Compound **9** (1.16 g, 5.0 mmol) was treated with acetic anhydride (3.06 g, 30.0 mmol) and DMAP (61 mg, 0.5 mmol) in dichloromethane (20 ml) at room temperature for 2 h. The organic layer was washed with water (3 x 20 ml), dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was purified on a silica gel column to give viscous liquid **10** (1.27 g, 93%). ^1H-NMR ($CDCl_3$): 6.98 (d, J = 8.6 Hz, 1H) Ar; 6.69 (dd, J = 2.9 Hz, 1H) Ar; 6.61 (d, 1H) Ar; 4.98 (dt, J = 4.6 Hz, 11.6 Hz, 1H) H-1; 3.76 (s, 3H) OMe; 2.84-2.72 (m, 3H) H-9, H-4_a; 2.31-2.25 (m, 1H) H-10_a; 2.08 (s, 3H) OAc; 1.86-1.43 (m, 8H) H-2, H-3, H-4, H-10. ^{13}C-NMR ($CDCl_3$): 170.2 (s) (C=O)Me; 157.3 (s) Ar; 136.8 (s) Ar; 133.0 (s) Ar; 129.6 (d) Ar; 113.0 (d) Ar; 111.8 (d) Ar; 74.8 (d) C-1; 54.9 (q) OMe; 39.2 (d) C-10_a; 37.8 (d) C-4_a; 30.8 (t) CH_2; 29.4 (t) C-9; 25.6 (t) CH_2; 23.8 (t) CH_2; 21.2 (q) OAc; 16.6 (t) C-10. HRMS calcd. for $C_{17}H_{22}O_3$: 274.1569. Found: 274.1567.

***cis*-1α-Acetoxy-7-methoxy-1, 2, 3, 4, 4a, 10a-hexahydro-9(10*H*)-phenanthrenone (5)**: Chromium trioxide (4.0 g, 40.0 mmol) was suspended in dichloromethane (20 ml) at -20 °C and DMP (3.84 g, 40.0 mmol) was added in one portion. After stirring at -20 °C for 15 min, compound **10** (548 mg, 2.0 mmol) in dichloromethane (5 ml) was added dropwise and the reaction mixture was stirred at -10 °C to -15 °C for 8 h. The reaction was poured into cold water (50 ml). The phases were separated and the aqueous layer was extracted with dichloromethane (2 x 20 ml). The combined organic layer was washed with water (2 x 15 ml) and brine (2

x 15 ml), dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was purified on a silica gel column to give **5** (311 mg, 54%).^{1}H-NMR (400 MHz, $CDCl_3$): 7.50 (d, J = 2.9 Hz, 1H) H-8; 7.17 (d, J = 8.4 Hz, 1H) H-5; 7.09 (dd, J = 2.9 Hz, 8.4 Hz, 1H) H-6; 5.00 (ddd, J = 4.4 Hz, 4.4 Hz, 11.0 Hz, 1H) H-1; 3.84 (s, 3H) OMe; 2.91 (ddd, J = 4.0 Hz, 4.0 Hz, 11.8 Hz, 1H) H-4a; 2.83 (m, 1H) H-10a; 2.77 (m, 1H) H-10; 2.68 (dd, J = 4.0 Hz, 16.1 Hz, 1H) H-10; 2.06 (s, 3H) OAc; 1.89 (m, 1H) H-3; 1.84 (m, 1H) H-2; 1.73 (m, 1H) H-4; 1.58 (m, 2H) H-2, H-3; 1.50 (m, 1H) H-4. The stereochemistry is assigned by NOEs between H-1 and both H-4a and H-10a, which indicate that these three protons must be on the same face of the ring system.^{13}C-NMR ($CDCl_3$): 197.8 (s) C=O; 170.2 (s) (C=O)Me; 158.4 (s) Ar; 140.2 (s) Ar; 132.2 (s) Ar; 129.8 (d) Ar; 122.3 (d) Ar; 108.9 (d) Ar; 73.4 (d) C-1; 55.5 (q) OMe; 39.5, 36.8 (2 x d) C-4_a, C-10_a; 33.4 (t) C-10; 29.3 (t) CH_2; 25.1 (t) CH_2; 23.5 (t) CH_2; 21.2 (q) OAc. Anal. calcd. for $C_{17}H_{20}O_4x1/4H_2O$: C, 69.7; H, 7.0. Found: C, 69.6; H, 7.2.

***cis*-1α-Acetoxy-7-hydroxy-1, 2, 3, 4, 4a, 9, 10, 10a-octahydrophenanthrene (11)**: To a solution of **10** (1.23 g, 4.5 mmol) in dichloromethane (15 ml) was added 1 N boron tribromide (9 ml, 9.0 mmol) in dichloromethane dropwise over 15 min at -78 °C. The reaction mixture was stirred at -78 °C for 30 min and then kept in a refrigerator for 16 h at -12 °C. The reaction mixture was poured into cold water (40 ml), extracted with diethyl ether (3 x 30 ml) and the combined organic layer washed with water (2 x 20 ml) and brine (2 x 15 ml), dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was purified on a silica gel column to give **11** (1.06 g, 91%). ^{1}H-NMR ($CDCl_3$): 6.81 (d, J = 8.3 Hz, 1H) Ar; 6.51 (dd, J = 2.7 Hz, 1H) Ar; 6.45 (d, 1H) Ar; 4.88 (dt, J = 5.3 Hz, 1H) H-1; 2.70-2.60 (m, 3H) H-9, H-4_a; 2.16 (m, 1H) H-10_a; 2.00 (s, 3H) OAc; 1.75-1.34 (m, 8H) H-2, H-3, H-4, H-10. ^{13}C-NMR ($CDCl_3$): 170.9 (s) (C=O)Me; 154.1 (s) Ar; 136.8 (s) Ar; 132.0 (s) Ar; 129.6 (d) Ar; 114.6 (d) Ar; 112.8 (d) Ar; 75.2 (d) C-1; 39.2 (d) C-10_a; 37.8 (d) C-4_a; 30.7 (t) CH_2; 29.0 (t) C-9; 25.5 (t) CH_2; 23.6 (t) CH_2; 21.1 (q) OAc; 16.4 (t) C-10. HRMS calcd. for $C_{16}H_{20}O_3$: 260.1412. Found: 260.1385.

***cis*-1α-7-Bisacetoxy-1, 2, 3, 4, 4a, 9, 10, 10a-octahydrophenanthrene (12)**: Compound **11** (1.04 g, 4.0 mmol) gave **12** (1.16 g, 96%) using similar conditions described above for **10**. ^{1}H-NMR ($CDCl_3$): 7.05 (d, J = 8.3 Hz, 1H) Ar; 6.82-6.79 (m, 2H) Ar; 4.98 (dt, J = 4.9 Hz, 11.5 Hz, 1H) H-1; 2.82-2.75 (m, 3H) H-9, H-4_a; 2.27 (s, m, 4H) OAc, H-10_a; 2.08 (s, 3H) OAc; 1.86-1.44 (m, 8H) H-2, H-3, H-4, H-10. ^{13}C-NMR ($CDCl_3$): 170.2 (s) (C=O)Me; 169.5 (s) (C=O)Me; 148.2 (s) Ar; 138.3 (s) Ar; 137.1 (s) Ar; 129.7 (d) Ar; 121.2 (d) Ar; 118.6 (d) Ar; 74.6 (d) C-1; 39.6 (d) C-4_a; 37.5 (d) C-10_a; 30.6 (t) CH_2; 29.1 (t) C-9; 25.6 (t) CH_2; 23.8 (t) CH_2; 21.2 (q) OAc; 20.9 (q) OAc; 16.4 (t) C-10. HRMS calcd. for $C_{18}H_{22}O_4$: 302.1518. Found 302.1520.

***cis*-1α-7-Bisacetoxy-1, 2, 3, 4, 4a, 10a-hexahydro-9(10*H*)-phenanthrenone (13)**: Compound **12** (906 mg, 3.0 mmol) gave **13** (393 mg, 41%) using similar conditions described above for **5**. ^{1}H-NMR ($CDCl_3$): 7.70 (d, J = 2.3 Hz, 1H) Ar; 7.26-7.24 (m, 2H) Ar; 5.00 (dt, J = 4.3 Hz, 11.2 Hz, 1H) H-1; 3.03-2.64 (m, 4H) H-10, H-4_a , H-10_a; 2.30 (s, 3H) OAc; 2.06 (s, 3H) OAc; 1.95-1.47 (m, 6H) H-2, H-3, H-4. ^{13}C-NMR ($CDCl_3$): 196.7 (s) C=O; 170.1 (s) (C=O)Me; 169.2 (s) (C=O)Me; 149.3 (s) Ar; 144.7 (s) Ar; 132.4 (s) Ar; 129.7 (d) Ar; 127.2 (d) Ar; 119.6 (d) Ar; 73.0 (d) C-1; 39.6, 36.4 (2 x d) C-4_a, C-10_a; 33.1 (t) C-10; 28.9 (t) CH_2; 24.9 (t) CH_2; 23.3 (t) CH_2; 21.0 (q) OAc; 20.8 (q) OAc. HRMS calcd. for $C_{18}H_{20}O_5$: 316.1311. Found 316.1308.

***cis*-1α-Acetoxy-7-[(trifluoromethyl)-sulfomyl]-1, 2, 3, 4, 4a, 9, 10, 10a-octahydrophenanthrene (14)**: A mixture of **11** (780 mg, 3.0 mmol) and Et_3N (1.21 g, 12.0 mmol) in dichloromethane (15 ml) was stirred under N_2 at room temperature for 1 h. N-Phenyltrifluoromethane- sulfonimide (1.61 g, 4.5 mmol) was added, and the reaction mixture was stirred for 48 h at room temperature. The mixture was washed with 10% aqueous sodium bicarbonate (3 x 10 ml) and water (2 x 10 ml), dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was purified on a silica gel column to give **14** (1.02 g, 86%). ^{1}H-NMR ($CDCl_3$): 7.11 (d, J = 8.3 Hz, 1H) Ar; 7.00 (dd, J = 2.6 Hz, 1H) Ar; 6.98 (d, 1H) Ar; 4.97 (dt, J = 4.6 Hz, 11.2 Hz, 1H) H-1; 2.95-2.71 (m, 3H) H-9, H-4_a; 2.34-2.24 (m, 1H) H-10_a; 2.08 (s, 3H) OAc; 1.92-1.35 (m, 8H) H-2, H-3, H-4, H-10. ^{13}C-NMR ($CDCl_3$): 170.3 (s) (C=O)Me; 147.3 (s) Ar; 141.2 (s) Ar; 138.4 (s) Ar; 130.5 (d) Ar; 121.1 (d) Ar; 118.2 (d) Ar; 74.4 (d) C-1; 39.6 (d) C-4_a; 37.3 (d) C-10_a; 30.6 (t) CH_2; 29.1 (t) C-9; 25.5 (t) CH_2; 23.8 (t) CH_2; 21.2 (q) OAc; 16.2 (t) C-10. HRMS calcd. for $C_{17}H_{19}F_3O_5S$: 392.0905. Found: 392.0906.

***cis*-1α-Acetoxy-1, 2, 3, 4, 4a, 9, 10, 10a-octahydrophenanthrene-7-methylester (15)**: A mixture of **14** (784 mg, 2.0 mmol), Et_3N (222 mg, 2.2 mmol), $Pd(OAc)_2$ (13 mg, 0.06 mmol), DPPP (49 mg, 0.12 mmol) and MeOH (3 ml) in DMF (40 ml) was degassed under N_2 for 10 min. The reaction mixture was heated at 70 °C under carbon monoxide (2.5 atmosphere) for 16 h. The reaction mixture was cooled, and poured into cold water. The aqueous layer was extracted with diethyl ether (3 x 75 ml) and the combined organic layer washed with water (4 x 50 ml) and brine (2 x 25 ml), dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was purified on a silica gel column to give **15** (460 mg, 76%), (m.p. = 98-101 °C, crystallised from diethyl ether). ^{1}H-NMR ($CDCl_3$): 7.75 (dd, 1H) Ar; 7.74 (d, 1H) Ar; 7.12 (d, J = 7.9 Hz, 1H) Ar; 4.99 (dt, J = 6.3 Hz, 11.5 Hz, 1H) H-1; 3.89 (s, 3H) CO_2Me; 2.93-2.78 (m, 3H) H-9, H-4_a; 2.33-2.28 (m, 1H) H-10_a; 2.09 (s, 3H) OAc; 1.89-1.37 (m, 8H) H-2, H-3, H-4, H-10. ^{13}C-NMR ($CDCl_3$): 170.3 (s) (C=O)Me; 167.0 (s) (C=O)Me; 146.0 (s) Ar; 135.9 (s) Ar; 130.2 (d) Ar; 128.9 (d) Ar; 127.5 (s) Ar; 126.5 (d) Ar; 74.5 (d) C-1; 51.8 (q) CO_2Me; 40.2 (d) C-4_a; 37.3 (d) C-10_a; 30.4 (t) CH_2; 28.9 (t) C-9; 25.6 (t) CH_2; 23.9 (t) CH_2; 21.2 (q) OAc; 16.6 (t) C-10. Anal. calcd. for $C_{18}H_{22}O_4$: C, 71.5; H, 7.3. Found: C, 71.5; H, 7.3.

***cis*-1α-Acetoxy-1, 2, 3, 4, 4a, 10a-hexahydro-9(10*H*)-phenanthrenone-7-methylester (16)**: Compound **15** (906 mg, 3.0 mmol) gave white solid **16** (475 mg, 57%, the yield is based on consumed starting material), (m.p. = 98-100 °C, crystallised from a mixture of diethyl ether and hexane) and unreacted starting material (106 mg, 12%) using similar conditions described above for **5**. ^{1}H-NMR ($CDCl_3$): 8.68 (d, J = 2.0 Hz, 1H) Ar; 8.16 (dd, 1H) Ar; 7.34 (d, J = 8.0 Hz, 1H) Ar; 5.01 (dt, J = 4.3 Hz, 10.9 Hz, 1H) H-1; 3.92 (s, 3H) CO_2Me; 2.83-2.72 (m, 4H) H-10, H-4_a, H-10_a; 2.06 (s, 3H) OAc; 1.91-1.42 (m, 6H) H-2, H-3, H-4. ^{13}C-NMR ($CDCl_3$): 196.8 (s) C-9; 170.2 (s) (C=O)Me; 166.1 (s) (C=O)Me; 151.7 (s) Ar; 134.2 (s) Ar; 131.4 (d) Ar; 129.1 (s) Ar; 128.9 (d) Ar; 128.7 (d) Ar; 72.9 (d) C-1; 52.2 (q) CO_2Me; 40.3 (d) C-4_a; 36.2 (d) C-10_a; 33.4 (t) CH_2; 28.7 (t) CH_2; 24.9 (t) CH_2; 23.4 (t) CH_2; 21.1 (q) OAc. Anal. calcd. for $C_{18}H_{20}O_5$: C, 68.4; H, 6.3. Found: C, 68.3; H, 6.2.

1-(2'-Methoxyphenyl)-4-(phenylthio)butanol (18): Compound **17** (3.06 g, 22.5 mmol) in THF (30 ml) was added to a solution of Grignard reagent prepared from magnesium (930 mg, 38.0 mmol) and 1-bromo-3-(phenylthio)propane (8.01 g, 34.5 mmol) in THF (20 ml) under N_2 at room temperature. The reaction mixture

was stirred for 3 h at room temperature and then quenched with saturated aqueous solution of ammonium choride (50 ml). The aqueous layer was extracted with diethyl ether (3 x 75 ml) and the combined organic layer washed with water (3 x 30 ml) and brine (2 x 20 ml), dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was purified on a silica gel column to give **18** (4.72 g, 73%). ^{1}H-NMR ($CDCl_3$): 7.42-6.93 (m, 9H) Ar; 4.96 (dd, J = 6.2 Hz, 1H) CHOH; 3.91 (s, 3H) OMe; 3.03 (t, J = 7.6 Hz, 2H) $PhSCH_2$; 2.76 (brs, 1H) OH; 2.05-1.77 (m, 4H) $\underline{CH_2}CHOH$, $SCH_2\underline{CH_2}$.^{13}C-NMR ($CDCl_3$): 156.4, 136.7, 132.1, 128.9, 128.8, 128.7, 128.3, 126.8, 125.6, 120.7, 110.4 (11-C) Ar-C; 70.4 (d) CHOH; 55.2 (q) OMe; 36.1 (t) CH_2; 33.5 (t) $PhSCH_2$; 25.6 (t) CH_2. HRMS calcd. for $C_{17}H_{20}O_2S$: 288.1184. Found: 288.1162.

1-(2'-Methoxyphenyl)-4-(phenylthio)butane (19): To a suspension of lithium aluminium hydride (190 mg, 5.0 mmol) in diethyl ether (10 ml) was added dropwise a solution of aluminium chloride (666 mg, 5.0 mmol) in diethyl ether (5 ml) at room temperature. After 5 min, a solution of **18** (1.44 g, 5.0 mmol) in ether (5 ml) was added dropwise during 30 min. The reaction mixture was stirred 16 h at gentle reflux, was cooled, and then 5% H_2SO_4 (10 ml) was added. The aqueous layer was extracted with diethyl ether (3 x 30 ml), and the combined organic layer was washed with saturated aqueous solution of sodium bicarbonate (3 x 30 ml) and water (3 x 30 ml), dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was purified on a silica gel column to give **19** (485 mg, 76%, the yield is based on consumed starting material) and unreacted starting material (760 mg, 53%). ^{1}H-NMR ($CDCl_3$): 7.35-7.11 (m, 7H) Ar; 6.91-6.83 (m, 2H) Ar; 3.82 (s, 3H) OMe; 2.96 (t, J = 7.1 Hz, 2H) $PhSCH_2$; 2.64 (t, J = 7.1 Hz, 2H) CH_2Ar; 1.76-1.68 (m, 4H) $\underline{CH_2}CH_2Ar$, $SCH_2\underline{CH_2}$.^{13}C-NMR ($CDCl_3$): 157.4, 136.9, 130.4, 129.7, 128.9, 128.7, 126.9, 125.6, 120.3, 110.2 (10-C) Ar-C; 55.2 (q) OMe; 33.5 (t) $PhSCH_2$; 29.6 (t) CH_2Ar; 28.9 (t) CH_2. HRMS calcd. for $C_{17}H_{20}O_2S$: 272.1235. Found 272.1237.

4-(2'-Methoxyphenyl)butanal (20): A solution of **19** (2.72 g, 10.0 mmol) in CCl_4 (40 ml) was added to a solution of NCS (1.60 g, 12.0 mmol) in CCl_4 (10 ml). The reaction mixture was stirred for 4 h under N_2 at the room temperature and then filtered, and the filtrate was concentrated at reduced pressure. Acetone (50 ml), water (1.5 ml), cupric oxide (3.42 g, 43.0 mmol), and cupric chloride dihydrate (3.42 g, 20.0 mmol) were added to the residue, and the mixture was refluxed for 20 min. The reaction mixture was cooled, diluted with diethyl ether (200 ml), and then filtered. The filtrate was washed with water (3 x 30 ml) and brine (3 x 20 ml), dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was purified on a silica gel column to give **20** (1.31 g, 74%). ^{1}H-NMR ($CDCl_3$): 9.68 (t, J = 1.7 Hz, 1H) CHO; 7.20-7.06 (m, 2H) Ar; 6.88-6.79 (m, 2H) Ar; 3.76 (s, 3H) OMe; 2.63 (t, J = 7.4 Hz, 2H) CH_2Ar; 2.37 (dt, J = 7.3 Hz, 2H) $\underline{CH_2}CHO$; 1.89 (m, 2H) $\underline{CH_2}CH_2Ar$.^{13}C-NMR ($CDCl_3$): 202.3 (d) CHO; 157.1, 129.6, 127.0, 120.0, 109.9 (5-C) Ar-C; 54.7 (q) OMe; 42.9 (t) $\underline{C}H_2CHO$; 29.1 (t) CH_2Ar; 21.9 (t) $\underline{C}H_2CH_2Ar$. HRMS calcd. for $C_{11}H_{14}O_2$: 178.0994. Found 178.0998.

1-(2'-Methoxyphenyl)-8-(phenylthio)-4-octanol (21): To the Grignard reagent prepared from magnesium (220 mg, 9.0 mmol) and 1-bromo-3-(phenylthio)butane (2.03 g, 8.3 mmol) in THF (10 ml) under N_2 at room temperature was added a solution of **20** (1.33 g, 7.5 mmol) in THF (20 ml). The reaction mixture was stirred at room temperature for 2 h and then quenched with a saturated aqueous solution of ammonium choride (20 ml). The aqueous layer was extracted with diethyl ether (3 x 30 ml) and the combined organic layer washed with water (3 x 20 ml) and brine (2 x 15 ml), dried over $MgSO_4$, filtered, and concentrated at reduced

pressure. The residue was purified on a silica gel column to give **21** (1.85 g, 72%). ^{1}H-NMR ($CDCl_3$): 7.33-7.10 (m, 7H) Ar; 6.88-6.82 (m, 2H) Ar; 3.81 (s, 3H) OMe; 3.57 (m, 1H) CHOH; 2.91 (t, J = 7.1 Hz, 2H) $PhSCH_2$; 2.67-2.55 (m, 2H) CH_2; 1.72-1.43 (m, 11H) 5 x CH_2, OH.^{13}C-NMR ($CDCl_3$): 157.2, 129.6, 128.7, 128.6, 126.8, 125.5, 120.2, 110.0 (8-C) Ar-C; 71.3 (d) CHOH; 55.1 (q) OMe; 36.9 (t) $\underline{C}H_2CHOH$; 36.6 (t) CH_2; 33.3 (t) $PhSCH_2$; 29.8 (t) CH_2Ar; 28.9 (t) CH_2; 25.7 (t) CH_2; 24.7 (t) CH_2. HRMS calcd. for $C_{21}H_{28}O_2S$: 344.1810. Found 344.1789.

1-(2'-Methoxyphenyl)-8-(phenylthio)-octan-4-one (22): To a suspension of celite (5 g) in dichloromethane (15 ml) was added PCC (pyridinium chlorochromate) (1.62 g, 7.5 mmol), and this was stirred under N_2 at room temperature for 30 min. A solution of **21** (1.72 g, 5.0 mmol) in dichloromethane (5 ml) was added to the PCC-Celite suspension. The reaction mixture was stirred at room temperature for 5 h and then filtered, and the filtrate was washed with diethyl ether (100 ml). The combined filtrates were concentrated at reduced pressure. The residue was passed through a short pad of silica gel column to give **22** (1.33 g, 78%). ^{1}H-NMR ($CDCl_3$): 7.36-7.07 (m, 7H) Ar; 6.89-6.81 (m, 2H) Ar; 3.78 (s, 3H) OMe; 2.89 (t, J = 7.0 Hz, 2H) $PhSCH_2$; 2.59 (t, J = 7.4 Hz, 2H) CH_2Ar; 2.41-2.36 (m, 4H) 2 x $(C{=}O)CH_2$; 1.90-1.82 (m, 2H) CH_2; 1.72-1.58 (m, 4H) 2 x CH_2. ^{13}C-NMR ($CDCl_3$): 210.6 (s) C=O; 157.4, 136.5, 129.9, 129.8, 128.9, 128.8, 127.1, 125.7, 120.2, 110.2 (10-C) Ar-C; 55.1 (q) OMe; 42.2 (t) (C=O) $\underline{C}H_2$; 41.9 (t) (C=O) $\underline{C}H_2$; 33.3 (t) $PhSCH_2$; 29.4 (t) CH_2Ar; 28.6 (t) CH_2; 23.8 (t) CH_2; 22.8 (t) CH_2. HRMS calcd. for $C_{21}H_{26}O_2S$: 342.1654. Found 342.1645.

2-[2-(2'-Methoxyphenyl)-ethyl]-2-cyclohexen-1-one (24): Method A: A solution of **22** (1.38 g, 4.0 mmol) in CCl_4 (5 ml) was added to a solution of NCS (700 mg, 5.2 mmol) in CCl_4 (15 ml). The reaction mixture was stirred for 4 h under N_2 at room temperature and then filtered, and the filtrate was concentrated at reduced pressure. Acetone (20 ml), water (0.6 ml), cupric oxide (1.27 g, 16.0 mmol), and cupric chloride dihydrate (1.36 g, 8.0 mmol) were added to the residue, and the mixture was refluxed for 30 min. The reaction mixture was cooled, diluted with ether (25 ml), and then filtered. The filtrate was washed with water (3 x 10 ml) and brine (2 x 10 ml), dried over $MgSO_4$, filtered, and concentrated at reduced pressure to give **23** (744 mg, crude weight). To a solution of the crude **23** (744 mg) in THF (15 ml) was added perchloric acid (1.0 g) and water (15 ml), and the solution was heated at reflux overnight: The reaction mixture was cooled and the phases were separated. The aqueous layer was extracted with diethyl ether (3 x 20 ml) and the combined organic layer washed with saturated aqueous solution of sodium bicarbonate (3 x 25 ml) and water (2 x 20 ml), dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was purified on a silica gel column to give **24** (233 mg, 25%, from **22** to **24**). ^{1}H-NMR (400 MHz, $CDCl_3$): 7.16 (ddd, J = 1.8 Hz, 7.4 Hz, 8.0 Hz, 1H) H-4'; 7.08 (dd, J = 1.8 Hz, 7.4 Hz, 1H) H-6'; 6.86 (ddd, J = 1.2 Hz, 7.4 Hz, 7.4 Hz, 1H) H-5'; 6.83 (dd, J = 1.2 Hz, 8.0 Hz, 1H) H-3'; 6.58 (tm, J = 4.2 Hz, 1H) H-2; 3.81 (s, 3H) OMe; 2.71 (dd, J = 7.2 Hz, 9.5 Hz, 2H) CH_2Ar; 2.46 (m, 2H), 2.42 (m, 2H), 2.28 (m, 2H), 1.95 (m, 2H). ^{13}C-NMR ($CDCl_3$): 200.2 (s) C=O; 157.2 (s) Ar; 145.2 (d) C-2; 138.9 (s) Ar; 129.9 (s) Ar; 129.7 (d) Ar; 126.8 (d) Ar; 120.0 (d) Ar; 109.8 (d) Ar; 54.9 (q) OMe; 38.3 (t)CH_2; 29.5 (t) CH_2; 28.8 (t) CH_2Ar; 25.8 (t) CH_2; 22.9 (t) CH_2. HRMS calcd. for $C_{15}H_{18}O_2$: 230.1307. Found 230.1305.

Method B: To a solution of *o*-anisic acid **25** (1.93 g, 12.7 mmol) in THF (20 ml) was added ammonia (50 ml) at -78 °C. Sodium (approximately 1g), washed sequentially with xylene and diethyl ether, was added in small

pieces. This gave a pale yellow solution, which, upon introduction of more sodium, changed to a blue color. The reaction mixture was stirred at -60 °C for 20 min. A solution of **26** (3.0 g, 14.0 mmol) in THF (5 ml) was added in reaction mixture dropwise during 15 min and the reaction mixture was stirred at -60 °C for further 1 h. The ammonia was removed by a water aspirator. The residue was diluted with water (15 ml), and concentrated HCl (10 ml), hydroquinone (40 mg) and 1, 2-dichloroethane (20 ml) were added in aqueous layer. The reaction mixture was refluxed for 30 min, cooled, extracted with 1, 2-dichloroethane (2 x 20 ml), and then the organic layer was washed with saturated aqueous solution of sodium bicarbonate (3 x 30 ml) and water (2 x 20 ml), dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was purified on a silica gel column to give **24** (840 mg, 29%).

2,3-Oxirano-[2-(2'-methoxyphenyl)-ethyl]-2-cyclohexan-1-one (27): A solution of sodium hydroxide (360 mg, 9.0 mmol) in water (1.5 ml) was added during 10 min to a solution of **24** (1.38 g, 6.0 mmol) and hydrogen peroxide (0.84 ml, 30% solution in water) in methanol (20 ml) at 0 °C. The reaction mixture was stirred at 10 °C-15 °C for 30 min and then diluted with water (25 ml) and extracted with diethyl ether (3 x 25 ml). The combined organic layers were washed with water (3 x 20 ml) and brine (2 x 20 ml), dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was purified on a silica gel column to give a viscous liquid **27** (1.24 g, 84%). ^{1}H-NMR ($CDCl_3$): 7.18 (dt, J = 2.0 Hz, 8.3 Hz, 1H) Ar; 7.06 (dd, J = 7.3 Hz, 1H) Ar; 6.89-6.81 (m, 2H) Ar; 3.80 (s, 3H) OMe; 3.09 (t, J = 1.8 Hz, 1H) epoxide-H; 2.75-2.69 (m, 2H) CH_2Ar; 2.58-2.47 (m, 2H); 2.14-1.74 (m, 3H); 1.68-1.54 (m, 3H). ^{13}C-NMR ($CDCl_3$): 205.8 (s) C=O; 157.2 (s) Ar; 129.9 (d) Ar; 127.3 (d) Ar; 120.3 (d) Ar; 110.1 (d) Ar; 61.5 (s); 60.9 (d) epoxide-C; 55.1 (q) OMe; 36.9 (t) CH_2; 29.6 (t) CH_2; 25.6 (t) CH_2Ar; 23.2 (t) CH_2; 17.5 (t) CH_2. HRMS calcd. for $C_{15}H_{18}O_3$: 246.1256. Found 246.1268.

(4aβ, 10aβ)-5-Methoxy-10a-hydroxy-3, 4, 4a, 9, 10-hexahydro-1(2*H*)-phenanthrenone (29): To a solution of **27** (1.23 g, 5.0 mmol) in dichloromethane (20 ml) was added dropwise $SnCl_4$ (2.60 g, 10.0 mmol) at -10 °C. The reaction mixture was stirred at room temperature for 16 h and then poured onto ice (30 g) and extracted with diethyl ether (3 x 25 ml). The combined organic layer was washed with 2 % HCl (15 ml), water (3 x 15ml) and brine (2 x 15 ml) and dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was purified on a silica gel column to give colourless crystalline **29** (1.02 g, 83%), (mp 142-145 °C, crystallised from diethyl ether). ^{1}H-NMR (400 MHz, $CDCl_3$): 7.12 (dd, J = 7.7 Hz, 8.0 Hz, 1H) H-7; 6.76 (d, J = 7.7 Hz, 1H) H-8; 6.68 (d, J = 8.0 Hz, 1H) H-6; 4.05 (s, 1H) OH; 3.79 (s, 3H) OMe; 3.15 (m, 1H); 3.15 (ddd, J = 6.6 Hz, 12.8 Hz, 17.2 Hz, 1H) H-9; 2.86 (dd, J = 6.5 Hz, 17.2 Hz, 1H) H-9; 2.63 (ddd, J = 6.2 Hz, 13.9 Hz, 20.0 Hz, 1H); 2.58 (m, 1H); 2.34 (m, 1H); 2.28 (ddd, J = 6.5 Hz, 12.8 Hz, 12.8 Hz, 1H) H-10; 2.10 (m, 1H); 1.81 (m, 1H); 1.60 (m, 1H)H-10. The position of the methoxy group at C-5 is indicated by an NOE between an aromatic proton, H-8 and proton H-9. The methoxy protons show an NOE exclusively to the aromatic proton H-6. ^{13}C-NMR ($CDCl_3$): 213.9 (s) C=O; 157.1 (s) Ar; 135.4 (s) Ar; 126.6 (d) Ar; 126.1 (s) Ar; 121.1 (d) Ar; 107.5 (d) Ar; 55.0 (q) OMe; 44.3 (d) C-4_a; 37.6 (t) CH_2; 30.9 (t) CH_2; 27.6 (t) CH_2; 25.7 (t) CH_2; 24.9 (t) CH_2. Anal. calcd. for $C_{15}H_{18}O_3$: C, 73.1; H, 7.3. Found: C, 73.1; H, 7.3.

5-Methoxy-1, 2, 3, 4, 9, 10-hexahydro-1-oxo-phenanthrene (30): A viscous solution of **29** (984 mg, 4.0 mmol) and PPA (polyphosphoric acid) (4 g) was heated at 90 °C for 6 h and then poured onto ice (30 g) and extracted with diethyl ether (3 x 20 ml). The combined organic phases were washed with saturated aqueous

solution of sodium bicarbonate (3 x 15 ml), water (3 x 15 ml) and brine (2 x 15 ml) and dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was purified on a silica gel column to give **30** (474 mg, 52%).^{1}H-NMR ($CDCl_3$): 7.22 (t, J = 7.9 Hz, 1H) Ar; 6.82-6.79 (dd, J = 1.0 Hz, 7.9 Hz, 1H) Ar; 6.81 (d, J = 8.3 Hz, 1H) Ar; 3.84 (s, 3H) OMe; 2.97-2.92 (m, 2H); 2.63 (t, J = 7.4 Hz, 1H) CH_2; 2.50 (t, J = 6.8 Hz, 1H) CH_2; 2.45-2.38 (m, 2H) CH_2; 2.03-1.95 (m, 2H) CH_2. ^{13}C-NMR ($CDCl_3$): 198.9 (s) C=O; 157.8 (s) Ar; 151.9 (s) Ar; 141.4 (s) Ar; 133.5 (s) Ar; 130.2 (d) Ar; 120.3 (d) Ar; 110.0 (d) Ar; 55.3 (q) OMe; 37.8 (t) CH_2; 30.4 (t) CH_2; 29.0 (t) CH_2; 23.6 (t) CH_2; 19.7 (t) CH_2. HRMS calcd. for $C_{15}H_{16}O_2$: 228.1150. Found 228.1152.

***cis*-1α-Hydroxy-5-methoxy-1, 2, 3, 4, 4a, 9, 10, 10a-octahydrophenanthrene (31)** and ***cis*-1β-hydroxy-5-methoxy-1, 2, 3, 4, 4a, 9, 10, 10a-octahydrophenanthrene (32)**: To the solution of **30** (69 mg, 0.3 mmol) in ethanol (5 ml) was added 2N NaOH (2 ml). Raney Ni (50 mg) was added and the mixture was stirred under hydrogen (1 atmosphere) at room temperature for 12 h, and thereafter filtered through a short pad of celite. The solids were washed with dichloromethane (20 ml). The combined organic layer was washed with dilute HCl (2 x 5 ml), water (3 x 5 ml) and brine (2 x 5 ml) and dried over $MgSO_4$, filtered, and concentrated at reduced pressure. The residue was passed through a short pad of silica gel column to give a mixture of **31** and **32** (65 mg, 93%). Compound **31** + **32** ^{1}H-NMR ($CDCl_3$): 7.08 (dt, J = 1.3 Hz, 7.9 Hz, 1H) Ar; 6.79-6.65 (m, 2H) Ar; 3.96-3.89 (m, 1H) H-1; 3.81 (s, 3H) OMe (major); 3.79 (s, 3H) OMe (minor); 3.39-2.54 (m, 3H); 2.13-1.26 (m, 9H). ^{13}C-NMR ($CDCl_3$): 157.3, 137.5, 137.1, 130.2, 126.0, 125.9, 119.9, 107.1, 107.0, 72.7 (d) C-1 (minor); 71.9 (d) C-1 (major); 55.0 (q) OMe; 40.9, 40.6, 34.6, 29.8, 29.7, 29.6, 29.5, 28.1, 27.5, 26.7, 24.1, 21.8, 19.8, 15.7. HRMS calcd. for $C_{15}H_{20}O_2$: 232.1463. Found 232.1475.

***cis*-1α-Acetoxy-5-methoxy-1,2, 3, 4, 4a, 9, 10, 10a-octahydrophenanthrene (33)** and ***cis*-1β-acetoxy-5-methoxy-1, 2, 3, 4, 4a, 9, 10, 10a-octahydrophenanthrene (34)**: A mixture of **31** and **32** (58 mg, 0.25 mmol) gave a mixture of **33** and **34** (52 mg, 76%) using similar conditions described above for **10**. Compound **33** + **34** ^{1}H-NMR ($CDCl_3$): 7.08 (t, J = 7.9 Hz, 1H) Ar; 6.71-6.64 (m, 2H) Ar; 5.05-4.96 (m, 1H) H-1; 3.92 (s, 3H) OMe (major); 3.83 (s, 3H) OMe (minor); 3.29-2.95 (m, 3H); 2.09 (s) OAc; 2.08 (s) OAc; 2.23-1.45 (m, 9H). ^{13}C-NMR ($CDCl_3$): 171.3 (s) (C=O)Me; 171.2 (s) (C=O)Me; 157.9, 157.6, 137.9, 137.6, 130.5 , 130.2, 127.0, 126.9, 122.1, 122.0, 107.8, 106.9, 75.9 (d) C-1 (minor); 75.3 (d) C-1 (major); 55.8 (q) OMe; 38.6, 38.4, 35.1, 31.2, 30.6, 28.7, 27.9, 27.5, 26.8, 26.3, 24.7, 22.2, 22.1, 21.4, 17.4.

***cis*-1β-Acetoxy-5-methoxy-1, 2, 3, 4, 4a, 10a-hexahydro-9(10*H*)-phenanthrenone (6)** and ***cis*-1α-acetoxy-5-methoxy-1, 2, 3, 4, 4a, 10a-hexahydro-9(10*H*)-phenanthrenone (35)**: A mixture of **33** and **34** (49 mg, 0.18 mmol) after oxidation using similar conditions described above for **5**, subsequent column chromatographic purification gave **6** (21 mg, 41%) and **35** (14 mg, 27%). Compound **6** ^{1}H-NMR (400 MHz, $CDCl_3$): 7.66 (dd, J = 1.1 Hz, 7.9 Hz, 1H) H-8; 7.28 (dd, J = 7.9 Hz, 8.1 Hz, 1H) H-7; 7.05 (dd, J = 1.1 Hz, 8.1 Hz, 1H) H-6; 4.94 (≈q, J = 2.0 Hz, 1H) H-1; 3.89 (s, 3H) OMe; 3.49 (ddd, J = 4.4 Hz, 4.4 Hz, 12.5 Hz, 1H) H-4_a; 2.74 (m, 1H) H-10; 2.55 (m, 1H) H-10; 2.50 (m, 1H) H-10_a; 2.11 (s, 3H) OAc; 1.99 (m, 1H) H-4_{eq}; 1.84 (m, 1H) H-2; 1.79 (m, 1H) H-3; 1.70 (m, 1H) H-3; 1.65 (m, 1H) H-2; 1.39 (m, 1H) H-4_{ax}. The position of methoxy group was determined as for **35**. The sterochemistry is indicated by the small coupling constant between H-1 and both H-2, and by a NOE between H-1 and one H-10. ^{13}C-NMR ($CDCl_3$): 197.2 (s)

C=O; 170.3 (s) (C=O)Me; 156.8 (s) Ar; 137.0 (s) Ar; 132.5 (s) Ar; 127.1 (d) Ar; 118.9 (d) Ar; 114.9 (d) Ar; 72.5 (d) C-1; 55.7 (q) OMe; 36.9 (t) C-10; 36.9 (d) C-10_a; 30.1 (d) C-4_a; 25.8 (t) C-4; 24.6 (t) C-2; 21.4 (q) OAc; 20.2 (t) C-3. Anal. calcd. for $C_{17}H_{20}O_4$: C, 70.8; H, 6.9. Found: C, 71.0; H, 6.7.

Compound **35** ^{1}H-NMR (400 MHz, $CDCl_3$): 7.65 (dd, J = 0.7 Hz, 8.0 Hz, 1H) H-8; 7.28 (dd, J = 8.0 Hz, 8.1 Hz, 1H) H-7; 7.05 (dd, J = 0.7 Hz, 8.1 Hz, 1H) H-6; 5.01 (ddd, J = 4.5 Hz, 4.5 Hz, 11.3 Hz, 1H) H-1; 3.87 (s, 3H) OMe; 3.29 (ddd, J = 3.7 Hz, 3.7 Hz, 12.3 Hz, 1H) H-4_a; 2.77 (m, 1H) H-10; 2.72 (m, 1H) H-10a; 2.64 (m, 1H) H-10; 2.06 (s, 3H) OAc; 1.91 (m, 1H) H-4_{eq}; 1.86 (m, 2H) H-2_{eq}, H-3_{eq}; 1.60 (m, 1H) H-2_{ax}; 1.54 (m, 1H) H-3_{ax}; 1.33 (m, 1H) H-4_{ax}. The position of methoxy group is indicated by an NOE exclusively to the aromatic proton H-6, as was observed for **29**. The sterochemistry is derived from NOEs between H-1 and both H-4a and H-10a, which all must be located on the same face of the ring system. ^{13}C-NMR ($CDCl_3$): 198.3 (s) C=O; 170.3 (s) (C=O)Me; 156.4 (s) Ar; 136.3 (s) Ar; 132.5 (s) Ar; 127.2 (d) Ar; 118.9 (d) Ar; 114.9 (d) Ar; 73.6 (d) C-1; 55.7 (q) OMe; 36.6 (d) C-10_a; 33.8 (d) C-4_a; 33.3 (t) C-10; 25.4 (t) CH_2; 25.3 (t) CH_2; 23.7 (t) CH_2; 21.2 (q) OAc. HRMS calcd. for $C_{17}H_{20}O_4$: 288.1362. Found 288.1359.

X-ray crystallography of (4aβ, 10aβ)-5-Methoxy-10a-hydroxy-3, 4, 4a, 9, 10-hexahydro-1(2H)-phenanthrenone (29): X-ray crystallography was carried out on a colourless crystal of **29**, which was obtained from a diethyl ether solution and a crystal with the dimensions 0.24x0.12x0.10 mm and was used for data collection on an Enraf-Nonius CAD-4 diffractometer. The angular settings of 25 reflections, with θ in the range of 27 - 45°, were measured to calculate the cell parameters. Intensity data for reflections with $\theta < 60^\circ$ were collected by the θ/2θ scan mode using graphite-monochromated Cu Kα radiation. Six intensity control reflections which were measured every 2 h showed no significant intensity variations. A total of 1838 unique reflections were measured out of which 1597 reflections with $I > 2.5(\sigma I)$ were considered observed. The intensities were corrected for Lorentz and polarization effects. No correction for absorption or extinction was made.
Crystal data: $C_{15}H_{18}O_3$, M_r = 246.31, monoclinic, $P2_1/a$, a =12.201(2), b = 7.261(1), c = 15.137(2) Å, β =110.39(1)°, V = 1257.0 Å^3, Z = 4, D_x = 1.302 g cm^{-3}, μ = 0.69 mm^{-1}. The structure was solved by direct methods which provided the location of the non-hydrogen atoms. The hydrogen atoms on the methyl group and the hydrogen on the hydroxyl group were located in a difference Fourier map, and all remaining hydrogens were placed in idealized positions with d(C-H) = 1.00 Å and B(H) = 1.2B_{eq} (parent atom). Refinement was carried out by the full-matrix least-squares refinement method using anisotropic temperature factors for the non-hydrogen atoms. The hydrogen atom parameters were not refined. After refinement, shift/e.s.d. < 0.001, using unit weights the R and R_w values were 0.062 and 0.060, respectively. The goodness of fit was 1.24 and the largest positive and negative peaks on a difference Fourier map were 0.28 and -0.29 e Å^{-3}. The NRCVAX[1] program system was used for all calculations.

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