Tetrahedron. Vol. 30, pp. 187 to 194 Pergamon Press 1974. Printed in Great Britain

SYNTHETIC STUDIES TOWARDS COMPLEX DITERPENOIDS—VII[1]

STEREOSELECTIVE SYNTHESIS AND CONFORMATIONAL ANALYSIS OF ALL FOUR POSSIBLE RACEMATES OF 1,2,3,4,4a,9a-HEXADYDRO-1-METHYLFLUORENE-1-CARBOXYLIC ACIDS

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(*Received in the UK* 30 *July* 1973; *Accepted for publication* 30 *August* 1973)

Abstract—Synthesis of the unsaturated acid **3** through H_2SO_4- catalysed cyclodehydration of the keto-ester **1** and its conversion to lactone **4** are described. The PPA induced cyclization of the keto-acid **9**, on the other hand resulted in a stereoisomeric mixture of the octahydroanthracene derivatives **10a** and **10b**. The four possible racemates of the hydrofluorene derivatives **5**, **6**, **7**, and **8** have been synthesized by chemical and catalytic reduction of **3** and **4**. Li-liquid ammonia induced reductive cleavage of the lactone **4** proceeds with 65% *retention* and 35% *inversion* of configuration at the benzylic C-4a asymmetric centre to afford the *trans* and *cis* acids **5** and **8** respectively, while catalytic hydrogenolysis of **4** proceeds with *inversion* to give the *cis* acid **8**. Li-liquid ammonia reduction of **3** gives *trans* acid **6** and *cis* **7** in 23% and 53% yields respectively, whereas catalytic hydrogenation of **3** affords 81% of *cis* acid **8** and 13% of *cis* acid **7**. Some conformational properties of the methyl esters **17**, **18**, **19**, and **20** have been deduced from chemical and NMR spectral data.

We presented earlier[2] the synthesis of a hydrofluorene derivative[3] related to gibberellins; and also the stereoselective syntheses of several hydrophenanthrene derivatives[4,5] for their ultimate conversion to gibberellins and related compounds.[6] In this paper we describe[7] the syntheses of model hydrofluorene derivatives, such as the lactone **4**, featuring the *gem*-methylcarboxylic acid γ-lactone function in a *trans*-hydrofluorene moiety (as present in the ring—A of the C_{19}-gibberellins) and the epimeric acids **5**, **6**, **7** and **8** (Scheme 1). We also studied the conformational configurational relationship of these compounds.

As in the present work we have essentially followed the general scheme (i→ii→iii→iv) developed[4] for the syntheses of the similar hydrophenanthrene derivatives; the major differences in the parallel studies in the hydrofluorene system relative to the corresponding hydrophenanthrene system will only be the points of discussions here.

Syntheses of intermediates and the lactone 4

Cyclization of the keto-ester **1** with cold concentrated H_2SO_4 in benzene solution afforded, as the sole product, the unsaturated ester **2** in 43% yield. Treatment of **1** with PPA under different experimental conditions was found to be unsatisfactory as it led to complex mixture from which separation of constituents was found to be difficult. Saponification of **2** yielded quantitatively the crystalline unsaturated acid **3**. The assignments of structures to **2** and **3** followed from their ultraviolet spectrum. When **3** alone or in $CHCl_3$ solution, was treated with cold concentrated H_2SO_4, the lactone **4** was obtained in only 20–30% yield;‡ the unchanged acid (70–80%) could, however, be recovered.

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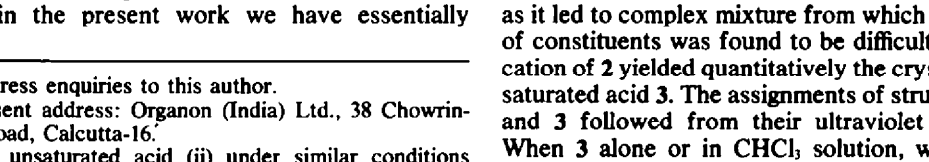
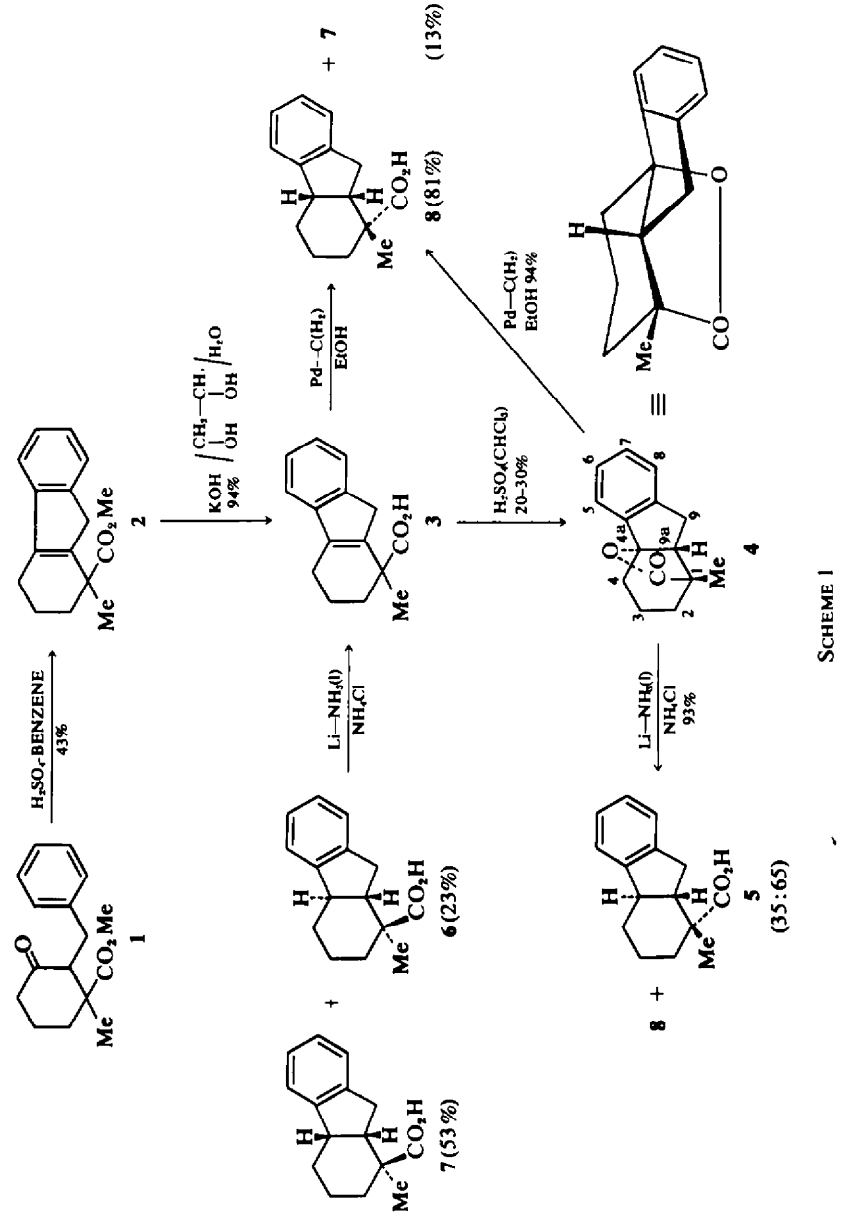
‡The unsaturated acid (ii) under similar conditions gave lactone (iii) in 70% yield (Ref. 4). This difference in the case of lactonization of the acids (ii) and **3** is probably due to the strain involved in the latter case.



SCHEME 1



SCHEME 1

Sterochemical assignment to the lactone **4** is based on conformational considerations[4] and also from analogy.[8] This has been confirmed through the direct chemical transformations to be described below. Attempted lactonization of **3** with H_2SO_4—HOAc, HCOOH or HBr—HOAc failed to produce any useful product.

Interesting results were obtained in the attempts for the direct transformation of the keto-acid **9** to the lactone **4** using PPA. When the keto-acid **9** was subjected to the conditions of Mori *et al.** a small amount of a semisolid material was obtained as the only neutral product. It showed strong bands centered at 1709 cm^{-1} and 1680 cm^{-1} and indicated absence of any γ-lactone function in the CO region in the IR. On a second trial at elevated temperature the same neutral material was obtained in 92% yield. The product was found to be a mixture of two components according to TLC. On crystallisation a solid 'A' (m.p. 131°) was obtained in about 30% yield. The light yellow gum left in the mother liquor initially indicated (TLC) the presence of 'A' as a minor constituent; but on standing the proportion of 'A' gradually increased. Chromatography of this mixture over acidic alumina transformed the whole material into the solid component 'A'. Several attempts to isolate the second component proved to be futile. From its spectral properties structure **10a** has been assigned to the stable isomer 'A', which corresponds well with the elemental analyses. The second component is obviously the less stable epimer **10b** which equilibrates at C-5 through enolization of C-4 keto function to the more stable isomer 'A'. The *trans* stereochemistry to the stable isomer 'A' has been assigned from an analogy with the known stability of the octahydroanthracene derivatives **11**[10] and **12**,[11] (and also the 4- and 6-oxo steroids[12]) this is, however, only tentative at this point as the presence of angular methyl group and the keto-group at C-4 may entirely change the order of thermodynamical stabilities[12a,b] of the diketones. Conformational analyses of **10a** and **10b** using Dreiding model show very little difference in energy between these two epimers, yet almost the complete transformation of the less stable to the stable epimer is surprising.

Syntheses of the epimeric acids **5**, **6**, **7** *and* **8**

Reductive cleavage of the lactone **4** with Li-liquid NH_3 afforded a mixture† of the *trans* acid **5** and the *cis* acid **8** in a ratio of approximately 65:35 (determined from NMR of the crude methyl ester) involving retention and inversion respectively at the benzylic asymmetric centre in **4**. In contrast, in the hydrophenanthrene series[4,5] similar reductive cleavage proceeded with complete retention leading only the *trans* acids. The pure acid **5** could be isolated by fractional crystallization of the reaction product. The stereochemistry of this acid was confirmed from the resistance of its methyl ester towards hydrolysis[4,5] (Table 1) and NMR studies (Table 2 and Table 3). As already mentioned,[4] the mechanistic picture of this cleavage retaining the stereochemistry at the benzylic centre in the carbanion **13** is not clear. In any event, this method constitutes an easy stereoselective synthesis of the difficultly accessible trans hydrofluorene system **5** retaining all the asymmetric centres corresponding to the ring A of gibberellins.

Table 1. The saponifications of the methyl esters **17**, **18**, **19** and **20** in 7% KOH in MeOH-H_2O (4:1) at the reflux for 2 h

Ester	Ester hydrolyzed, %*	Recovered ester, %*
17	25	72
18	97	ca 2
19	48	48
20	65	34

*Based on the isolated crude products.

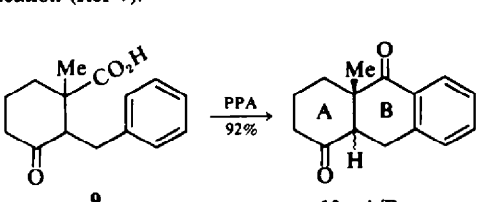
Table 2. NMR spectral data for methyl esters **17**, **18**, **19** and **20**

Compound	Chemical shift* in $CDCl_3$	
	C-1 Me	C-1 COOMe
17	1·29	3·62
18	1·28	3·66
19	1·22	3·68
20	1·36	3·68

*Determined on a Varian HA-100 instrument and reported as δ-units relative to TMS (δ = 0).

*These authors (Ref 9) reported the conversion of (i) (R = H) to the lactone (iii) by reaction with PPA.

†From the TLC and m.p. behaviour this was erronously referred to as a pure isomer **5** in our preliminary communication (Ref 7).



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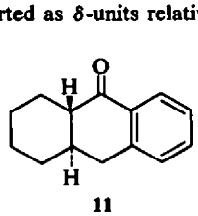
10a, A/B *trans*
10b, A/B *cis*



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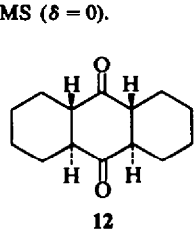

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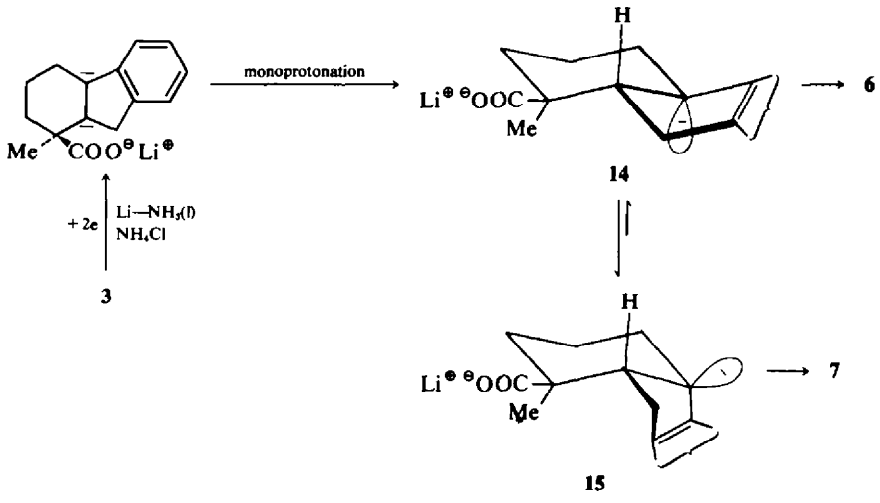
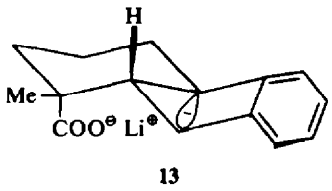
Li-liquid NH_3 reduction[13] of the unsaturated acid **3** led to a mixture from which the *trans* acid **6** and the *cis* acid **7** were isolated in 23% and 53% yields respectively through fractional crystallizations. The stereochemical assignment to the acids **6** and **7** has been advanced[4,13] from considerations of the intermediate stages **14** and **15** in the metal-NH_3 reduction of **3**, due to the influence of neighbouring carboxylic acid group (*shown below*). This was further confirmed through the stereoselective synthesis of the remaining *cis* epimer **8**, saponification studies of the methyl esters **17–20** (Table 1), NMR studies of the esters (Table 2) and alcohols **21–24** (Table 3).





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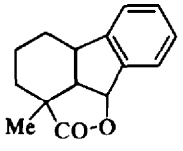


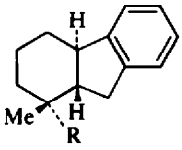
16

Catalytic hydrogenolysis of the lactone **4** in EtOH in presence of Pd-C at atmospheric temperature and pressure yielded the acid **8**, in excellent yield. The same acid was also obtained in 81% yield, along with the epimeric acid **7** (13%) through catalytic hydrogenation of the unsaturated acid **3** in presence of Pd-C. The configurational assignments of the epimeric acids **7** and **8** were based on the following considerations. Formation of these acids through a rapid process of hydrogenation[4,5] of the styrenoid bond of the unsaturated acid **3** reasonably established their depicted *cis* A/B ring junction. It has been well-established in our previous studies[4] that hydrogenolysis of the lactones of the type **4** involves inversion at the benzylic asymmetric center, similar to those observed[14] during hydrogenolysis of asymmetric benzyl alcohol in presence of Pd-C. Similar inversion at the benzylic asymmetric center (C-4a) in the lactone should lead to the acid **8**. The firm establishment of the stereochemistry of the acid **8** automatically leads to the assignment of stereo-structures to the epimeric *cis* acid **7**, which is further confirmed from its formation through lithium-ammonia reduction of the unsaturated acid **3** (loc cit).

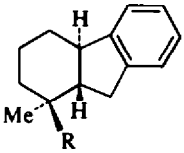
It is noteworthy that the selectivity in the absorption of hydrogen from the opposite face of the neighbouring carboxylic acid group in a *gem*-methyl-carboxylic acid moeity appears to be a general case.[4,5] The formation of the two stereoisomeric acids **5** and **8** from the lactone **4** through reductive cleavages at C-4a with *retention* and *inversion* of configuration respectively finally establishes the stereo-structure assigned to this lactone with unequivocal exclusion of the structure **16**.

Saponification rates of the esters **17**, **18**, **19**, *and* **20**

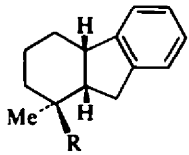
To confirm the assignments of the stereochemistry of the acids **5**, **6**, **7**, and **8**, and to evaluate the conformation of these compounds with respect to the corresponding hydrophenanthrene derivatives previously reported,[4] a qualitative comparative study of the relative rates of hydrolysis of the esters **17**, **18**, **19**, and **20** was undertaken. The results of this study are summarized in Table 1.



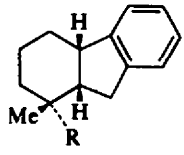
17, R = CO_2Me
21, R = CH_2OH



18, R = CO_2Me
22, R = CH_2OH



19, R = CO_2Me
23, R = CH_2OH



20, R = CO_2Me
24, R = CH_2OH

These data reveal that the saponification rates of the conformationally rigid *trans* esters **17** and **18** are quite consistant[4] with their assigned stereostructures **17a** and **18a** respectively, with *axial* and *equatorial* orientation of the methoxycarbonyl group. In contrast to the corresponding hydrophenanthrene analogous[4] the flexible *cis* esters **19** and **20** showed saponification rates comparatively close to each other and in between the axial *trans*-ester **17** and equatorial *cis*-ester **18**. These data are, however, sufficiently different to predict, at least qualitatively, by the preference of the "nonsteroid" forms **19a** and **20a** over the "steroid" forms **19b** and **20b** for these esters,[4,15] assuming chair like conformation for ring A. The hydrofluorene esters **17** and **19** (in the conformation **19a**), having axial methoxycarbonyl group show considerably higher saponification rates in comparison with those of the corresponding hydrophenanthrene analogous.[4] These can be accounted for due to the distortion[16] of the chair conformation of cyclohexane ring (ring A) from the fusion with planer cyclopentene ring (ring B) in the hydrofluorene derivatives, resulting in the relative displacement of the axial ester group and the C-4a hydrogen from each other. Examination of molecular models suggests this possibility.

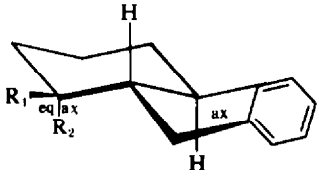
NMR studies. The significant data of the proton chemical shifts of the epimeric esters **17–20** are given in Table 2.

Table 3. NMR spectral data of the alcohols **21**, **22**, **23**, and **24**

Compound	Chemical shift[a] in $CDCl_3$	
	C-1 Me	C-1 CH_2OH
21	1·0	3·74[b]
22	0·97	3·39[c]
23	0·98	3·54[b]
24	1·10	3·41[b]

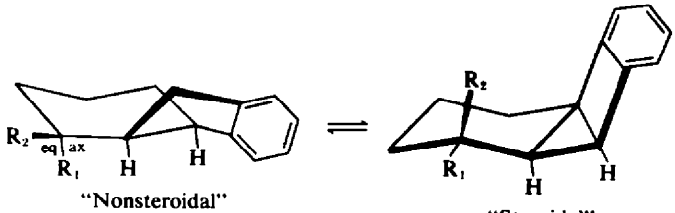
[a]Determined on a Varian HA-100 instrument and reported as δ units relative to TMS ($\delta = 0$).
[b]Centre of AB quartet.
[c]Singlet.

The differences in the chemical shifts of the C-1 Me group in these compounds, although not significant, are in order with those of the corresponding hydrophenanthrene derivatives analyzed in details in our previous paper.[4] It can be assumed that the hydrofluorene derivatives **17–20** have the same relative conformations, as have been established for the hydrophenanthrene analogous. These conformational deductions have been further sup-



A/B-trans

17a, R_1 = Me; R_2 = CO_2Me
18a, R_1 = CO_2Me; R_2 = Me



"Nonsteroidal"
A/B-cis

"Steroidal"

19a, R_1 = CO_2Me; R_2 = Me
20a, R_1 = Me; R_2 = CO_2Me

19b
20b

ported by the NMR spectra of the alcohols **21**–**24**, given in Table 3.

Examination of the NMR data of alcohols **21** and **22** clearly indicates[4] that the hydroxymethyl function in the former epimer is axially disposed as the methylene protons resonate at 0·35 ppm lower field[17] with respect to the CH_2OH group of **22**, which must be equatorially oriented. Evidence for the "nonsteroid" conformations of the flexible *cis* isomers **23** and **24** is also apparent[4] from the difference of the chemical shfts of 0·13 ppm between the CH_2-OH group of these epimeric alcohols. The NMR data supports the chemical evidence that the *cis* esters **19** and **20** have the conformational preferences of "non-steroid" forms **19a** and **20a** over the corresponding "steroid" forms **19b** and **20b**.

EXPERIMENTAL*

1-Carbomethoxy-1-methyl-1, 2, 3, 4-tetrahydrofluorene (**2**). In a 3-necked flask fitted with a stirrer and a dropping funnel was placed 20 g of **1**[2] in 400 ml dry thiophene-free benzene. The mixture was cooled in an ice-salt bath (− 5°) and pre-cooled conc H_2SO_4 (300 ml) was added dropwise to the vigorously stirred mixture over a period of 1 h. It was stirred in the cold (− 5° to 0°) for additional 30 min, and poured on to crushed ice. The aqueous layer was extracted with ether and the combined organic layer was washed with 5% Na_2CO_3aq and dried (Na_2SO_4). The solvent was evaporated and distillation of the residual yellow oil afforded 8·1 g (43%) of the ester **2**, b.p. 138–140° (0·3 mm); λ_{max} 260 nm (ϵ 10,700); ν_{max} 1710 cm^{-1}. (Found: C, 78·95; H, 6·96. $C_{16}H_{18}O_2$ requires: C, 79·31; H, 7·49%).

1 - Carboxy - 1 - methyl - 1, 2, 3, 4 - tetrahydrofluorene (**3**). The ester **2** (8·5 g, 35 m mole) was heated to reflux for 1 h in a soln of KOH (5 g, 89 m mole) water (5 ml) and ethylene glycol (50 ml) under N_2. The cooled mixture was diluted with water and the unhydrolysed ester was extracted with ether. Acidification of the cooled aqueous layer with 6 N HCl and subsequent working up afforded the crude acid **3** as a light yellow solid, which was crystallised from ether-light petroleum to colorless cubes (7·5 g; 94%), m.p. 146–147°; λ_{max} 260 nm (ϵ 15,800). (Found: C, 78·74; H, 7·18. $C_{15}H_{16}O_2$ requires: C, 78·92; H, 7·06%).

4aα-Hydroxy-1β-methyl-1, 2, 3, 4, 4a, 9a-hexahydrofluoren-1α-carboxylic acid 1→4a lactone (**4**). Powdered unsaturated acid **3** (1 g) was added in portions to well-stirred conc H_2SO_4 (30 ml) cooled in an ice-NaCl bath (*ca* −10°) during 20 min; [alternatively, the acid **3** was dissolved in dry $CHCl_3$ (30 ml) and added dropwise]. Stirring in the cold was continued for 30 min. The red mixture was poured on to crushed ice and extracted with ether. The extract was wahsed with 5% Na_2CO_3aq, water and dried (Na_2SO_4). After evaporation of solvent 250 mg (25%) of lactone **4**, m.p. 150–152° was obtained. Recrystallisation from ether afforded flakes, m.p. 154°; λ_{max} 260 nm (ϵ 1,050), 266 nm (ϵ 1,170) and 273 nm (ϵ 1,100); ν_{max} 1762 cm^{-1}. (Found: C, 78·84; H, 6·78. $C_{15}H_{16}O_2$ requires: C, 78·92; H, 7·06); 700 mg (70%) of acid **3**, m.p. and m.m.p. 146–147° was recovered from the alkaline washings on acidification with HCl and extraction with ether.

10-Methyl-4, 9-dioxo-1, 2, 3, 4, 5, 6, 9, 10-trans(?)-octahydroanthracene (**10a**). Compound **9**[2] (1·0 g) was added to well-stirred PPA (prepared from 4 g of P_2O_5 and 3 ml H_3PO_4) at 82–84°. The stirring was continued for 1 h at the same temp when the color turned from yellow to brown. On cooling the mixture was decomposed with crushed ice and extracted repeatedly with ether. The ethereal extract was washed with 5% Na_2CO_3 aq, water and dried (Na_2SO_4). Evaporation of solvent gave a light yellow gum (850 mg, 92%) which showed two sharp spots in TLC; IR spectrum: 1709 and 1682 cm^{-1}. The ethereal soln of this was left in the ice-box when a solid separated which, on crystallization from ether, afforded 300 mg (32%) of **10a** as shining colorless cubes, m.p. 131°; λ_{max} 250 nm (ϵ 13,490), 290 nm (ϵ 1,740); ν_{max} 1708 (s), 1682 (s) and 1600 cm^{-1} (m). NMR ($CDCl_3$ at 60 MHz with TMS internal standard), δ 1·05 (s, 3, C—10—CH_3), 2·09 (m, 4, C—1 and C—2—CH_2—), 2·4(m, C—5—methine and C—3—CH_2—), 2·8 (broad d, J = 2 ~ 3 Hz, 2, C—6 benzylic), 7·2–8·15 (m, 4 aromatic protons). (Found: C, 78·54; H, 6·96. $C_{15}H_{16}O_2$ requires: C, 78·92; H, 7·06%).

The concentrated mother liquor (400 mg) on attempted crystallisation from EtOAc-light petroleum or on prolonged standing produced more of the diketone indicated by gradual appearance of the spot corresponding at **10a** and disappearance of the other one in TLC. It was finally chromatographed through acidic alumina. Elution with petroleum ether-benzene (1:2) afforded 380 mg more of **10a**.

Hydrogenolysis of lactone **4** *with* Li-NH_3(*l*)

Preparation of 1α-carboxy-1β-methyl-trans-1,2,3,4, 4aα, 9a-hexahydrofluorene (**5**). A soln of **4** (1 g; 4·38 m mole) in 25 ml dry THF was added to about 250 ml anhyd liquid NH_3 distilled directly from the cylinder in a 3-necked flask fitted with a stirrer and a drying tube (KOH). Small pieces of Li wire (300 mg, 43 m mole) were added to the well-stirred mixture over *ca* 5–10 min period. Stirring was continued for further 5 min. NH_4Cl was added to discharge the blue color and ammonia was allowed to evaporate at room temp. The residue was taken up in water, acidified with cold 6N HCl and extracted with ether. The extract was washed with sat Na_2CO_3aq. The combined alakaline washing was acidified and extracted with ether after saturation with NaCl. The ether layer was washed with water, dried (Na_2SO_4) and solvent evaporated to give 930 mg, (93%) of white solid, m.p. 195–198°. TLC of this product showed a single spot in several solvent systems. A small portion of this product was esterified with ethereal CH_2N_2 and NMR of this ester mixture in $CDCl_3$ at 100 MHz showed two C-Me signals (*ca* δ 1·29 and 1·36). From the integrations as well as from the NMR comparison with the pure esters **17** and **20**, the ratio

*The compounds described here are all racemates and the terms α,β- have only relative significance. M.ps (taken in open capillary in H_2SO_4-bath) and b.ps are uncorrected. Unless mentioned otherwise, the homogeneity of each compound was checked through TLC plates coated with silica gel G (E. Merck, 200 mesh) of thickness of *ca* 0·2 mm using mixed solvent systems of light petroleum-benzene and EtOAc—$CHCl_3$, and I_2 vapour as developing agent. Pet. ether refers to the fraction b.p. 60–80°, light petroleum to the fraction b.p. 40–60°. UV were determined in 95% EtOH, in a Beckman DU-spectrophotometer by Mr. A. Ghosal, and the IR were determined in $CHCl_3$ solution, on a PE model-21 double beam recording spectrophotometer. Microanalyses were performed by Mrs Chhabi Dutta. We express our thanks for these services.

of **17** and **20** were determined to be approximately 65:35. Repeated fractional crystallization of the acid mixture from ether-light petroleum afforded a pure sample of **5** as colorless cubes m.p. 202°; no pure sample of **8** could be separated from the mother liquor; λ_{max} 260 nm (ϵ 810), 266 nm (ϵ 1,150) and 273 nm (ϵ 1,070). (Found: C, 78·36; H, 7·67. $C_{15}H_{18}O_2$ requires: C, 78·23; H, 7·88%).

1α - *Carbomethoxy* - 1β - *methyl* - trans - 1, 2, 3, 4, 4aα, 9a-*hexahydrofluorene* (**17**). Acid **5** (100 mg) was esterified with ethereal CH_2N_2 and the crude ester was purified by a short path distillation at 140° (bath temp; 0·3 mm) to afford 93 mg of **17**, λ_{max} 261 nm (ϵ 1,000), 267 nm (ϵ 1,070) and 274 nm (ϵ 1,020). (Found: C, 78·42; H, 8·32. $C_{16}H_{20}O_2$ requires: C, 78·65; H, 8·25%).

Li-NH_3(l) Reduction of the unsaturated acid **3**

Preparation of 1β-*carboxy*-1α-*methyl*-trans-1, 2, 3, 4, 4aα, 9a-*hexahydrofluorene* (**6**) *and* 1β-*carboxy*-1α-*methyl*-*cis*-1,2,3,4. 4aβ, 9a-*hexahydrofluorene* (**7**). A soln of **3** (1 g; 4·38 m mole) in 25 ml dry THF was added to about 250 ml anhyd liquid NH_3. The mixture was well-stirred and 450 mg (65 m mole) of Li, cut into small pieces was added over about 6 min. After addition of Li was complete, the blue soln was stirred for an additional 7 min and decomposed with solid ammonium chloride. The NH_3(l) was allowed to evaporate, the residue was dissolved in water and the mixture was acidified with 6 N HCl. The product was extracted with ether, washed into 2% NaOH aq and re-extracted with ether after saturation with NaCl. Work-up in the usual manner yielded 950 mg of white solid. Fractional crystallization from EtOAc-ether yielded the acid **7**, m.p. 187–88°, as the major product (530 mg, 53%); λ_{max} 261 nm (ϵ 1,000), 266 nm (ϵ 1,120) and 273 nm (ϵ 1,120). (Found: C, 77·95; H, 8·11. $C_{15}H_{18}O_2$ requires: C, 78·23; H, 7·88%).

The mother liquor afforded a higher melting acid which was crystallized from EtOAc to afford 230 mg (23%) of the pure epimeric acid **6**, m.p. 202–203°, depressed considerably on admixture with acid **5**, m.p. 202°; λ_{max} 260 nm (ϵ 890), 266 nm (ϵ 1,170) and 273 nm (ϵ 1,120). (Found: C, 78·54; H, 7·78. $C_{15}H_{18}O_2$ requires: C, 78·23; H, 7·88%).

1β-*Carbomethoxy*-1α-*methyl*-trans-1, 2, 3, 4, 4aα, 9a-*hexahydrofluorene* (**18**). The acid **6** (100 mg) was esterified with ethereal CH_2N_2. The crude ester was purified through evaporative distillation at 140° (bath temp; 0·3 mm) to afford 96 mg of **18**; λ_{max} 261 nm (ϵ 1,000), 266 nm (ϵ 1,070) and 274 nm (ϵ 1,020). (Found: C, 78·29; H, 8·07. $C_{16}H_{20}O_2$ requires: C, 78·65; H, 8·25%).

1β-*Carbomethoxy*-1α-*methyl*-cis-1,2,3,4,4aβ, 9a-*hexahydrofluorene* (**19**). The acid **7** (100 mg) was esterified with diazomethane. The crude ester was purified by a short path distillation at 140° (bath temp; 0·3 mm) to afford 95 mg of **19**; λ_{max} 261 nm (ϵ 1,000), 266 nm (ϵ 1,120) and 273 nm (ϵ 1,120). (Found: C, 78·35; H, 8·22. $C_{16}H_{20}O_2$ requires: C, 78·65; H, 8·25%).

Hydrogenolysis of lactone **4** *with* Pd-C

Preparation of 1α - *carboxy* - 1β - *methyl* - cis - 1,2,3,4, 4aβ, 9a-*hexahydrofluorene* (**8**). The lactone **4** (44 mg) in 10 ml abs EtOH was hydrogenated in the presence of 10 mg 10% Pd-C catalyst at room temp and pressure. The uptake of H_2 was very rapid and absorption essentially ceased within 5 min. The catalyst was filtered off; evaporation of solvent gave 38 mg (94%) of a white solid, m.p. 180°, which after recrystallization from ether-light petroleum afforded 35 mg of **8**, m.p. 181–182°, λ_{max} 261 nm (ϵ 1,020), 266 nm (ϵ 1,120) and 273 nm (ϵ, 1,050). (Found: C, 78·11; H, 7·87. $C_{15}H_{18}O_2$ requires: C, 78·23; H, 7·88%).

1α-*Carbomethoxy*-1β-*methyl*-cis-1,2,3,4,4aβ, 9a-*hexahydrofluorene* (**20**). The acid **8** (100 mg was esterified with ethereal CH_2N_2. The crude ester on evaporative distillation at 140° (bath temp; 0·3 mm) afforded 95 mg (95%) of the ester **20**; λ_{max} 261 nm (ϵ 1,020), 267 nm (ϵ 1,070) and 274 nm (ϵ, 1,020). (Found: C, 78·43; H, 8·34. $C_{16}H_{20}O_2$ requires: C, 78·65; H, 8·25%).

Catalytic reduction of the unsaturated acid **3**

Preparation of the acids **7** *and* **8**. The unsaturated acid **3** (800 mg) in 25 ml of abs EtOH (or HOAc) was hydrogenated in presence of 10% Pd-C catalyst (100 mg) at room temp and pressure. The uptake of H_2 was quite rapid. The catalyst was filtered off and the solvent was removed to afford 800 mg of crude product which was subjected to fractional crystallization from ether-light petroleum. The major product (650 mg, 81%) was found to be identical with the acid **8**, m.p. and m.m.p. 181–82°. The combined mother liquor was allowed to evaporate slowly at room temp whereupon a colorless solid, m.p. 183–86°, separated. Recrystallisation from ether yielded 105 mg (13%) of the other epimeric *cis* acid **7**, m.p. and m.m.p. 187–88°.

Saponifications of esters **17**, **18**, **19**, *and* **20**. Each of the esters 150 mg in 5 ml of 7% KOH soln in 4:1 MeOH:H_2O was refluxed under N_2 for 2 h. The unsaponified ester was repeatedly extracted with ether after dilution with sat NaClaq (25 ml). After acidification of the aq layer with 6 N HCl, the corresponding acid was isolated by repeated extraction with ether. The products were characterised by m.m.p. or IR. The results are given in Table 1.

Preparation of alcohols **21**, **22**, **23** *and* **24**. Each of the acids **5**, **6**, **7**, and **8** (30 mg) in 25 ml of dry THF was treated with a large excess of LAH. After heating at reflux for 6 h, the excess hydride was decomposed with EtOAc and sat Na_2SO_4aq. The organic layer was washed with 10% NaOHaq and water and dried over Na_2SO_4. Evaporation of solvent gave essentially quantitative yield of the alcohols which were purified through evaporative distillation at 140–45° (bath temp, 0·2 mm). (Found: Mol. Wts. (mass spectrometry) 216. $C_{15}H_{20}O$ requires: Mol. Wt. 216).

Acknowledgements—We are deeply indebted to Dr. R. E. Moore, University of Hawaii, Honolulu for the NMR spectra and valuable suggestions, to Dr. C. R. Enzell, Swedish Tobacco Company, Stockholm, for the Mass spectra, and to Dr. A. K. Banerjee for some preliminary experiments.

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