141.0–143.0°. *Anal.* Calcd. for $C_{22}H_{22}O_8$: C, 63.76; H, 5.35; OCH_3, 22.47; sapon. equiv., 414. Found: C, 63.72, 63.75; H, 5.44, 5.43; OCH_3, 22.64, 22.45; sapon. equiv., 416.

The saponification equivalent was determined by treating a warm, ethanolic solution of the lactone with excess 0.1 *N* sodium hydroxide, allowing the mixture to stand 0.5 hour at room temperature and back-titrating. If the mixture was boiled, variable, low values were obtained depending on the duration of the boiling. From this treatment a keto acid XIIb was recovered whose mixed melting point with an authentic sample was undepressed.

The keto lactone formed a yellow precipitate with 2,4-dinitrophenylhydrazine, but the product did not exhibit a sharp melting point despite repeated recrystallizations.

α-Benzyl-β-(α'-hydroxybenzyl)-butyrolactone (XVII).—A mixture of 2.38 g. (0.0085 mole) of the crystalline keto lactone XVa, 50 ml. of ethanol and 0.5 g. of 10% palladium–charcoal was shaken with hydrogen at room temperature and atmospheric pressure. The absorption of one molar equivalent of hydrogen was complete within 20 minutes. After removal of the catalyst and concentration of the solution, there was obtained 1.18 g. (49%) of white solid, m.p. 150–160°. Recrystallization of this substance from 5 ml. of ethanol gave 1.01 g. (42%) of product, m.p. 149–160°. A sample which was recrystallized from benzene–petroleum ether melted at 149–160°. *Anal.* Calcd. for $C_{18}H_{18}O_3$: C, 76.57; H, 6.43. Found: C, 77.4, 77.41; H, 6.50, 6.48. This material was also prepared by the palladium-catalyzed hydrogenation of the keto lactone in cyclohexane. The same wide melting range was observed.

An isomeric hydroxy lactone XVII was obtained by the palladium-catalyzed hydrogenation of 3.9 g. (0.014 mole) of the non-crystalline keto lactone XVa in ethanol. The absorption of 0.92 molar equivalent of hydrogen was complete in 6 hours. The hydroxy lactone crystallized on concentration of the solution and was recrystallized from benzene–petroleum ether to give 1.11 g. (28%) of product, m.p. 102–104°. An analytical sample melted at 103.0–103.6°. *Anal.* Calcd. for $C_{18}H_{18}O_3$: C, 76.57; H, 6.43. Found: C, 76.61, 76.77; H, 6.62, 6.49.

α-(3,4,5-Trimethoxybenzyl)-β-(α'-hydroxy-3',4'-methylenedioxybenzyl)-butyrolactone (II).—A mixture of 4.14 g. of the keto lactone XVb, 1.3 g. of 10% palladium–charcoal and 50 ml. of ethanol was shaken with hydrogen at room temperature and atmospheric pressure. The absorption of one molar equivalent of hydrogen took place in 3.5 hours, after which the rate slowed markedly. The glassy product was very resistant to crystallization but a sample eventually crystallized from ethyl acetate–petroleum ether, m.p. 100–105°. A solution of 3.5 g. of the crude glassy product in a mixture of ethyl acetate (45 ml.) and petroleum ether (60 ml.) was seeded and kept at −20° for several days. There was obtained 2.53 g. (72%) of white powder, m.p. 102–108°. Two more recrystallizations gave 1.87 g. (53%) of product, m.p. 104–108°. *Anal.* Calcd. for $C_{22}H_{24}O_8$: C, 63.45; H, 5.81; OCH_3, 22.36. Found: C, 63.61, 63.35; H, 6.13, 5.81; OCH_3, 22.36, 22.42. The infrared spectrum showed absorptions at 2.80 and 5.67 μ, consistent with the presence of hydroxyl and γ-lactone functions.

α-(3,4,5-Trimethoxybenzyl)-β-(3',4'-methylenedioxybenzoyl)-butyric Acid (XIX).—Hydrogenation of the non-crystalline fraction obtained from the reaction of the keto acid XVIII with formaldehyde took place with a very rapid initial uptake of hydrogen. Approximately 13% of an acid melting at 166–167° without decomposition was isolated. Analysis indicated that it was the keto acid XIX which could arise from hydrogenation of the corresponding methylene keto acid. The similarity between the infrared spectra of the product and the keto acid XIIb supports this structure. *Anal.* Calcd. for $C_{22}H_{24}O_8$: C, 63.45; H, 5.81; OCH_3, 22.36; neut. equiv., 414. Found: C, 63.84, 63.90, 63.85; H, 5.99, 5.85, 5.89; OCH_3, 22.53, 22.65; neut. equiv., 415.

Acknowledgments.—We wish to thank Dr. Mary H. Aldridge, Miss Kathryn Gerdeman and Mr. Byron Baer for performing the microanalyses. We are indebted to the National Cancer Institute, National Institutes of Health, Bethesda, Maryland, and to E. I. du Pont de Nemours and Co., Wilmington, Delaware. for generous grants in support of this work.

COLLEGE PARK, MARYLAND

[CONTRIBUTION FROM THE CHEMISTRY DEPARTMENT, UNIVERSITY OF MARYLAND]

Podophyllotoxin and Picropodophyllin. III.[1] The Synthesis of a Stripped Analog[2]

BY NATHAN L. DRAKE AND WILLIAM B. TUEMMLER[3]

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The synthesis of a lactone derived from 1-hydroxy-2-hydroxymethyl-4-phenyltetralin-3-carboxylic acid (Xa or b) is described. This represents a stripped analog of podophyllotoxin. The condensation of ethyl formate with acylic γ-keto esters appears to be prevented or greatly inhibited by the steric effect of an α-substituent. The cyclic γ-keto ester, 4-phenyl-3-carbethoxytetralone-1, condenses readily with ethyl formate.

In the course of a synthesis of an open-chain analog of podophyllotoxin,[1] the problem arose of converting the γ-keto acid I to the hydroxy lactone III. Two approaches were considered: (1) the condensation of I with formaldehyde followed by lactonization and reduction of the keto group, and (2) the condensation of the ethyl ester II with ethyl formate followed by reduction of the hydroxymethylene ketone system to the diol and lactonization. Because of the difficulties often encountered in formaldehyde condensations, the latter approach was investigated first.

Repeated attempts to formylate the keto ester II using sodium methoxide as described by Johnson and co-workers[4] as well as sodium hydride and potassium *t*-butoxide afforded at best only traces of enolic material. The only crystalline product isolated proved to be the enol lactone IV which evidently arose from an intramolecular attack of the enolate oxygen on the ester carbonyl. Attempted formylation of the ring-substituted keto ester (preceding paper) was likewise unsuccessful.

Since the formylation of cyclic ketones has been a widely used reaction, comparison of the reaction with the cyclic analog VII was made. This substance was prepared essentially according to Hewitt.[5] It was found advantageous to reduce the

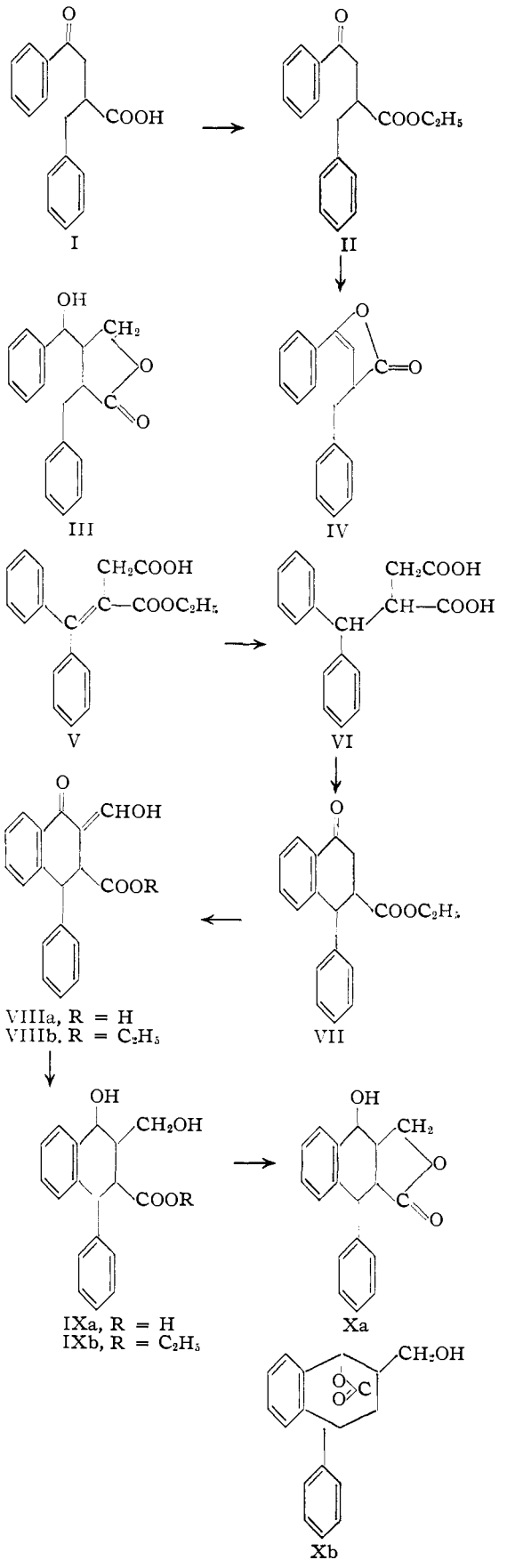
(1) Previous paper, N. L. Drake and W. B. Tuemmler, THIS JOURNAL, **77**, 1204 (1955).

(2) From a thesis submitted to the Graduate School of the University of Maryland by William B. Tuemmler in partial fulfillment of the requirements for the Ph.D. degree, July, 1953.

(3) Du Pont Fellow, 1952–1953.

(4) W. S. Johnson, J. M. Anderson and W. E. Shelberg, THIS JOURNAL, **66**, 218 (1944).

(5) C. L. Hewitt, *J. Chem. Soc.*, 596 (1936).



Stobbe product V by the method of Schwenk and Papa[6] instead of using sodium amalgam.

The keto ester VII readily underwent condensation with ethyl formate in the presence of sodium methoxide. In one experiment, a 61% yield of the hydroxymethylenecarboxylic acid VIIIa was obtained. When a short reaction time was employed, the hydroxymethylenecarboxylic ester VIIIb was formed. The reaction was remarkable in that a clear, red solution was formed even though benzene was the solvent and two moles of sodium methoxide per mole of keto ester was employed. In the experiment from which the hydroxymethylenecarboxylic acid was isolated, a precipitate did form on standing overnight.

The ease with which the cyclic keto ester underwent formylation indicates that a steric factor constitutes the important difference between it and the acyclic compound II. Molecular models show that the methylene group of the acyclic compound is considerably more hindered than that of the cyclic compound. Consequently, condensation is suppressed and competitive reactions such as enol lactone formation take precedence. The flexible nature of the acyclic system permits enolactonization while this is prevented in the cyclic molecule by its rigidity.

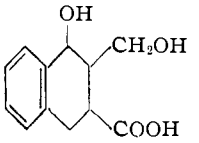
Since a steric factor appeared to prevent the desired condensation from taking place with II, the reaction was examined with acyclic keto esters which would present less hindrance to the condensation. Ethyl β-benzoylpropionate reacted rapidly with ethyl formate to give a 50% yield of enolic material. No decision was made as to which of the two methylene groups entered into the reaction although it was assumed that condensation alpha to the keto group predominated. Borsche[7] has reported that condensation of benzaldehyde with ethyl β-benzoylpropionate occurs alpha to the keto group. Under the same conditions, ethyl α-methyl-β-benzoylpropionate yielded only 8% of crude enolic material accompanied by a complex neutral fraction the composition of which was not established. The existence of branching adjacent to the methylene group in the acyclic series apparently results in sufficient hindrance to prevent or greatly inhibit condensation at the methylene group, and side reactions predominate.

The availability of VIIIa and b prompted an attempt to reduce them to the diol IX a procedure which would afford a stripped analog of podophyllic acid. The problem of synthesizing such a material was first undertaken by Borsche[8] who outlined the essential details of the present synthesis. However, the reported experimental work followed a somewhat different route, and the desired product was not obtained by Borsche.

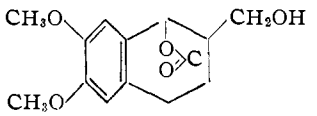
Reduction of VIIIa or VIIIb by sodium borohydride in aqueous alkali afforded the same dihydroxy acid IXa which lactonized on heating. When the reduction of VIIIb was performed in absolute ethanol, a low yield of the dihydroxycarboxylic ester IXb was obtained. Although it might be

(6) E. Schwenk, D. Papa, B. Whitman and H. F. Ginsberg, *J. Org. Chem.*, **9**, 175 (1944).
(7) W. Borsche, *Ber.*, **47**, 1108 (1914).
(8) W. Borsche, *Ann.*, **526**, 1 (1936).

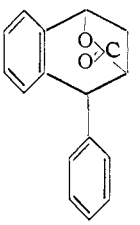
assumed that lactonization of IXa would lead to the less strained lactone Xa, infrared studies on the analogous lactone formed from XI indicate that the secondary hydroxyl participates in lactonization.[9] A similar assignment of configuration in the case of XII was made by Campbell and coworkers.[10] We have obtained the strained lactone XIII by heating the *cis*-hydroxy acid, although the yield was lower than in the case of X.[11] Thus, no positive assignment of the position of lactonization is possible on the basis of present evidence, since the strained configuration Xb cannot be excluded from consideration.



XI



XII



XIII

Experimental[12]

Benzhydrylsuccinic Acid (VI).—Benzhydrylidenesuccinic acid ester (V)[13] was reduced by the method of Schwenk and Papa[5] with simultaneous saponification. The crude acid was dried by heating its benzene solution under reflux and removing the benzene–water azeotrope and then crystallized from a mixture of benzene and ethyl acetate. Analysis and weight loss on anhydride formation indicated that the acid was obtained as the hemibenzeneate. On this basis, the yield of product, m.p. 184–187°, was 86%. *Anal.* Calcd. for $C_{17}H_{16}O_4 \cdot {}^1/_2C_6H_6$: C, 74.28; H, 5.92; neut. equiv., 161. Found: C, 73.96, 74.03; H, 5.85, 5.92; neut. equiv., 159, 159, 161.

4-Phenyl-3-carbethoxytetralone-1 (VII).—This keto ester was prepared in 35% yield from benzhydrylsuccinic acid. The reported yields[5] of 75% in the cyclization could not be duplicated; there was obtained only 37% of the keto acid, m.p. 211–213°. The use of cyclizing agents such as sulfuric acid, polyphosphoric acid and hydrogen fluoride was likewise unsatisfactory.

The keto ester readily formed a **2,4-dinitrophenylhydrazone** which melted at 267–268° dec. after recrystallization from ethyl acetate. *Anal.* Calcd. for $C_{25}H_{22}O_6N_4$: C, 63.28; H, 4.67; N, 11.81. Found: C, 63.33, 63.35; H, 4.68, 4.50; N, 11.85, 11.99.

4-Phenyl-3-carbethoxy-2-hydroxymethylenetetralone-1 (VIIIb).—A chilled suspension of 2.34 g. of alcohol-free sodium methoxide in 25 ml. of dry benzene containing 3.21 g. of ethyl formate under nitrogen was treated all at once with a solution of 6.38 g. of 4-phenyl-3-carbethoxytetralone-1 in 100 ml. of benzene. The red mixture was stirred in an ice-bath. After one-half hour, the sodium methoxide had dissolved, giving a clear, red solution. After an additional 10 minutes, 100 ml. of cold water was added. The light red, aqueous solution was washed with ether to remove turbidity and acidified under ether. The pale yellow ethereal solution was washed with sodium bicarbonate and dried over magnesium sulfate. Removal of the ether afforded 6.0 g. (86%) of amber oil which gave an immediate, deep-red color with ferric chloride. Although this material was not extracted by sodium bicarbonate, it was possible to titrate it with aqueous sodium hydroxide to the phenolphthalein end-point. Titration of the crude hydroxymethylenecarboxylic ester indicated a purity of 87%; the yield of pure material was thus 75%.

Purification of the crude enol *via* the copper chelate afforded a 58% recovery of amber oil having a neutralization equivalent of 324 (theory 322). Although a small amount of solid, m.p. 65–75°, could be obtained upon recrystallization from petroleum ether, attempts to obtain crystalline material suitable for analysis were unsuccessful. The enol formed an immediate, blood-red precipitate, m.p. 150–160° dec., when treated with 2,4-dinitrophenylhydrazine. Attempts to purify this product also were unsuccessful.

Concentration of the original benzene solution from the reaction afforded a small amount of white solid which melted at 229–232° after several recrystallizations from benzene. *Anal.* Found: C, 78.03, 78.20; H, 5.52, 5.60. The identity of this material was not established.

4-Phenyl-3-carboxy-2-hydroxymethylenetetralone-1 (VIIIa).—In an experiment similar to the above, except that the reaction mixture stood at 5° overnight, there was obtained a 61% yield of the hydroxymethylenecarboxylic acid, m.p. 189–191°. An analytical sample prepared by recrystallization from 1:1 benzene–petroleum ether, melted at 190–191°. *Anal.* Calcd. for $C_{18}H_{14}O_4$: C, 73.46; H, 4.79; neut. equiv., 147. Found: C, 73.09, 73.08; H, 4.83, 4.71; neut. equiv., 150.5, 150.

4-Phenyl-3-carboxy-2-hydroxymethyl-1-hydroxytetralin (IXa).—A solution of 0.40 g. of VIIIa in sodium hydroxide solution was treated with 0.3 g. of sodium borohydride and allowed to stand overnight at room temperature. Acidification precipitated a white, granular solid which gave no color with alcoholic ferric chloride. Recrystallization from a mixture of ethyl acetate and petroleum ether afforded 0.18 g. (45%) of dihydroxy acid. The material melted with decomposition at 187–188° and rapidly resolidified to the lactone, m.p. 229–233°. The melting point of the dihydroxy acid depended on the rate of heating; values of 188–189.5° and 187.5–188° were obtained on purified samples which were heated rapidly and slowly, respectively. *Anal.* Calcd. for $C_{18}H_{18}O_4$: C, 72.47; H, 6.08. Found: C, 72.47, 72.61; H, 6.38, 6.38.

The same product was obtained in 25% yield by reduction of the hydroxymethylencarboxylic ester by sodium borohydride in aqueous alkali for 6 hours.

4-Phenyl-3-carbethoxy-2-hydroxymethyl-1-hydroxytetralin (IXb).—A solution of 1.0 g. of crude VIIIb in 10 ml. of absolute ethanol was treated with 0.5 g. of sodium borohydride. The mixture stood 5 days at room temperature, after which time a sample gave a negative ferric chloride test. The ethanol was removed, and the residue was dissolved in water. Acidification precipitated a gum from which there was isolated a small amount of solid which melted at 128–131.5° after several recrystallizations from benzene–petroleum ether. *Anal.* Calcd. for $C_{20}H_{22}O_4$: C, 73.59; H, 6.80. Found: C, 73.37, 73.39; H, 6.89, 6.92.

Lactone of 4-Phenyl-3-carboxy-2-hydroxymethyl-1-hydroxytetralin.—A sample of 0.3555 g. of dihydroxy acid was heated at 195° until no further gas evolution was observed (5–10 minutes). The residual, neutral solid weighed 0.3315 g.; for the loss of one molecule of water, the residual solid should have weighed 0.3341 g. This represents a weight loss 12% greater than expected.

The lactone proved to be difficult to recrystallize. Recrystallization from 50% aqueous acetic acid afforded material which sintered at 235° and melted at 240–243°. An analytical sample was prepared by heating a pure sample of the dihydroxy acid under nitrogen. *Anal.* Calcd. for $C_{18}H_{16}O_3$: C, 77.12; H, 5.75; sapon. equiv., 280. Found: C, 77.37, 77.20; H, 5.53, 5.75; sapon. equiv., 272.

4-Phenyl-3-carbethoxy-1-hydroxytetralin.—A solution of 2.94 g. of 4-phenyl-3-carbethoxytetralone-1 in 30 ml. of 1 *M* aluminum isopropoxide in isopropyl alcohol was heated under a short fractionating column until the distillate gave

(9) S. Mednick, Ph.D. Thesis, University of Maryland, 1953.

(10) K. N. Campbell, R. J. Boyle and B. K. Campbell, paper presented before the Division of Medicinal Chemistry, 124th Meeting of the American Chemical Society, Chicago, Illinois, September 6–11, 1953.

(11) A similar strained lactone was reported by G. N. Walker, THIS JOURNAL, **75**, 3393 (1953), after the completion of this work.

(12) Melting points are corrected; boiling points are uncorrected. The petroleum ether employed in this work was the 60–80° fraction (Skelly B) supplied by the Skelly Oil Co.

(13) G. H. Daub and W. S. Johnson, THIS JOURNAL, **72**, 501 (1950).

no test for acetone (4 hours). The solvent was removed, and the residue was treated with dilute hydrochloric acid. The mixture was extracted with ether, and the ethereal solution was washed with sodium bicarbonate and dried over magnesium sulfate. A portion of the residue remaining after removal of the ether was recrystallized to give material melting at 116–117°. *Anal.* Calcd. for $C_{19}H_{20}O_3$: C, 77.00; H, 6.80. Found: C, 77.03, 77.20; H, 7.13, 7.07.

Lactone of *cis*-1-Hydroxy-3-carboxy-4-phenyltetralin (XIII).—Saponification of the above crude hydroxy ester mixture afforded 1.9 g. (70%) of hydroxy acids, m.p. 150–158° dec. Upon recrystallization from a mixture of ethyl acetate (40 ml.) and petroleum ether (150 ml.), there was obtained 1.5 g. of product, m.p. 163–165° dec.

A sample of 0.716 g. of the hydroxy acid mixture, m.p. 163–165° dec., was heated for several minutes at 180°. The resulting glass was taken up in ether, and the *trans*-hydroxy acid was removed by sodium bicarbonate. Concentration of the dried ether solution gave 0.53 g. of crude lactone, m.p. 100–125°. This was recrystallized from 50% aqueous acetic acid to give a product which sintered at 120° and melted at 125–127°. Sublimation at 110° (0.01 mm.) afforded material melting at 126–128°. *Anal.* Calcd. for $C_{17}H_{14}O_2$: C, 81.58; H, 5.64. Found: C, 81.93, 81.86; H, 5.93, 5.83.

***trans*-1-Hydroxy-3-carboxy-4-phenyltetralin.**—Acidification of the sodium bicarbonate extract obtained above afforded 0.09 g. of *trans*-hydroxy acid which melted at 191–193° after two recrystallizations from ethyl acetate–petroleum ether. *Anal.* Calcd. for $C_{17}H_{16}O_3$: C, 76.10; H, 6.01. Found: C, 76.12, 75.92; H, 6.02, 6.13.

***cis*-1-Hydroxy-3-carboxy-4-phenyltetralin.**—Saponification of the lactone XIII produced the *cis*-hydroxy acid, m.p. 169–170° dec. *Anal.* Calcd. for $C_{17}H_{16}O_3$: C, 76.10; H, 6.01. Found: C, 76.02, 76.04; H, 6.25, 6.23.

Ethyl α-Methyl-β-benzoylpropionate.—A solution of 21.1 g. of α-methyl-β-benzoylpropionic acid,[14] m.p. 138–142°, in 500 ml. of 1% ethanolic hydrogen chloride stood at room temperature for 24 hours. The residue remaining after removal of the ethanol was freed of acid and distilled. There was obtained 20.6 g. (85%) of the ethyl ester, b.p. 93° (0.1 mm.), $n^{25}D$ 1.5060, sp. gr. 25/25 1.0733. *Anal.* Calcd. for $C_{13}H_{16}O_3$: C, 70.89; H, 7.32; sapon. equiv., 220. Found: C, 71.19, 70.94; H, 7.36, 7.34; sapon. equiv., 219.

Acknowledgments.—We would like to express our thanks to Dr. Mary H. Aldridge and Miss Kathryn Gerdeman for performing the microanalyses. This work was supported in part by generous grants from the National Cancer Institute, National Institutes of Health, Bethesda, Maryland, and E. I. du Pont de Nemours and Co., Wilmington, Delaware, for which we are indebted.

(14) S. Dixon, H. Gregory and L. F. Wiggins, *J. Chem. Soc.*, 2139 (1949).

COLLEGE PARK, MARYLAND

[CONTRIBUTION FROM THE RESEARCH LABORATORIES OF THE UPJOHN COMPANY]

A Synthesis of Progesterone from Ergosterol[1]

BY D. A. SHEPHERD, R. A. DONIA, J. ALLAN CAMPBELL, B. A. JOHNSON, R. P. HOLYSZ, G. SLOMP, JR., J. E. STAFFORD, R. L. PEDERSON AND A. C. OTT

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A new and practical synthesis of progesterone from ergosterol, involving an improved method for the preparation of 4,22-ergostadien-3-one from 4,6,22-ergostatrien-3-one and conversion of the dienone to 3-ketobisnor-4-cholenaldehyde, is described.

The discovery[2a] and confirmation[2b] of a practical method for the conversion of progesterone to cortisone, *via* an 11-oxygenated intermediate produced biochemically, has emphasized the need for cheap progesterone in large quantities. Of the naturally-occurring sterols, ergosterol always has been an extremely attractive starting material because of its almost unlimited potential supply from fermentation processes. Only recently, however, has ergosterol served as the percursor of intermediates obviously useful in the preparation of steroid hormones,[3] and in these cases attention was centered on the preparation of 11-oxygenated *allo* compounds *via* reaction of the $\Delta^{7,9(11)}$ system.

This paper presents an efficient and practical synthesis of progesterone from ergosterol.

4,7,22-Ergostatrien-3-one (ergosterone, II)[4] was obtained in 77% yield by the Oppenauer oxidation of ergosterol (I) with cyclohexanone and aluminum isopropoxide in boiling toluene. The reaction proceeded with surprising rapidity, being essentially complete in 10 minutes as indicated by the rapid disappearance of the maximum (282 mμ) of ergosterol and the rapid rise of the maximum (242 mμ) of the Δ^4-3-ketone in the ultraviolet spectra of samples isolated consecutively from the reaction mixture.

Treatment of a hot solution of 4,7,22-ergostatrien-3-one in methanol with a small amount of concentrated hydrochloric acid caused the immediate precipitation of a white crystalline material. On the bases of its analysis, which showed the presence of a methoxyl group, and of its spectra typical of the $\Delta^{3,5,7}$- system, λ_{max} 321 mμ and maxima at 1571, 1620 and 1643 cm.$^{-1}$, this compound was assigned the

(1) Presented before the Division of Organic Chemistry at the 124th Meeting of the American Chemical Society, Chicago, Ill., September 6–11, 1953. A. F. Daglish, J. Green and V. D. Poole, *Chem. and Ind.*, **45**, 1207 (1953); *J. Chem. Soc.*, 2627 (1954), have since reported a synthesis of progesterone by a similar method. See also F. Johnson, G. T. Newbold and F. S. Spring, *J. Chem. Soc.*, 1302 (1954).

(2) (a) D. H. Peterson and H. C. Murray, THIS JOURNAL, **74**, 1871 (1952); H. C. Murray and D. H. Peterson, U. S. Patent 2,602,769; D. H. Peterson, H. C. Murray, S. H. Eppstein, L. M. Reineke, A. Weintraub, P. D. Meister and H. M. Leigh, THIS JOURNAL, **74**, 5933 (1952); (b) O. Mancera, A. Zaffaroni, B. A. Rubin, F. Sondheimer, G. Rosenkranz and C. Djerassi, *ibid.*, **74**, 3711 (1952); J. Fried, R. W. Thoma, J. R. Gerke, J. E. Herz, M. N. Donin and D. Perlman, *ibid.*, **74**, 3962 (1952).

(3) E. M. Chamberlin, W. V. Ruyle, A. E. Erickson, J. M. Chemerda, L. M. Aliminosa, R. L. Erickson, G. E. Sita and M. Tishler, *ibid.*, **73**, 2396 (1951); E. Schoenewaldt, L. Turnbull, E. M. Chamberlin, D. Reinhold, A. E. Erickson, W. V. Ruyle, J. M. Chemerda and M. Tishler, *ibid.*, **74**, 2696 (1952); L. F. Fieser, J. C. Babcock, J. E. Herz, Wein-Yuan Huang and W. P. Schneider, *ibid.*, **73**, 4053 (1951); H. Heusser, K. Eichenberger, P. Kurath, H. R. Dällenbach and O. Jeger, *Helv. Chim. Acta*, **34**, 2106 (1951); R. Budziarek, F. Johnson and F. S. Spring, *J. Chem. Soc.*, 3410 (1952); E. R. H. Jones, *et al.*, *ibid.*, 4883, 4890, 4894 (1952); 2009 (1953).

(4) (a) R. J. Oppenauer, *Rec. trav. chim.*, **56**, 137 (1937); (b) F. Wetter and C. Dimroth, *Ber.*, **70B**, 1665 (1937); (c) I. M. Heilbron, T. Kennedy, F. S. Spring and G. Swain, *J. Chem. Soc.*, 869 (1938).