The Synthesis of Potential Androgens. Part I.

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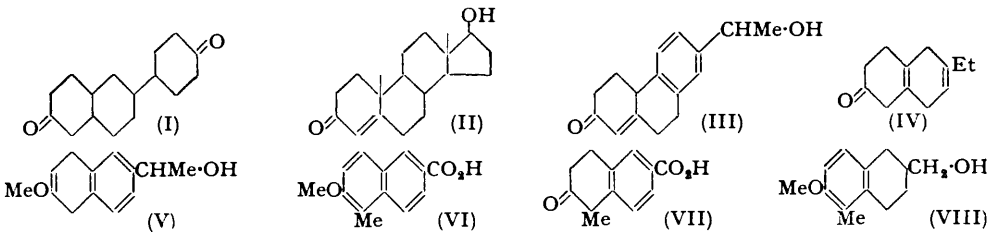
Several unsaturated ketones have been prepared by reduction of methoxy-substituted aromatic compounds with sodium and liquid ammonia, in attempts to obtain for androgenic testing substances bearing a superficial resemblance in structure to testosterone.

AFTER the preparation by Wilds and Shunk (*J. Amer. Chem. Soc.*, 1949, **71**, 3266) of a compound (I) containing part of the testosterone (II) skeleton and reported to be feebly androgenic, it was resolved to synthesise other substances in the hope of finding androgenic activity combined with similar partial hormone constitution.

The αβ-unsaturated cyclic ketone structure present in testosterone should be accessible in simpler compounds either by the Mannich base ring-extension method or by reduction of a methoxy-substituted aromatic nucleus with sodium and liquid ammonia, followed by hydrolysis and subsequent isomerisation of the βγ-unsaturated ketone produced. In an attempt to synthesis the ketone (III) by a combination of these methods, 2-acetyl-6-methoxynaphthalene was reduced to the secondary alcohol by Pondorff's method. When this was treated with an excess of sodium in liquid ammonia and alcohol, complete reduction occurred, the product after hydrolysis being 6-ethyl-1 : 2 : 3 : 4 : 5 : 8-hexahydro-2-oxonaphthalene (IV); use of the calculated amount of sodium however gave the dihydro-compound (V) in good yield. The latter with mineral acid could not be hydrolysed without partial dehydration, and this series of reactions was not pursued further.

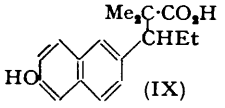


The acid (VI) was available from other work and it was thought possible, though unlikely, that sodium–ammonia reduction of this would lead to the ketone (VII) in which the carboxyl group occupies a position suitable for the addition of the sterol ring D. The free acid could not be reduced, but the ethyl ester was readily reduced, as expected, in the ring carrying the ester substituent, and at the same time at the ester group itself, the product being the alcohol (VIII). This subsidiary result was however not studied further.

It was thought that, despite the inactivity of the substance prepared by Birch and Mukherji (*J.*, 1949, 2531) by the reduction of hexœstrol, reduction of the potent œstrogen (IX) (Horeau and Jaques, *Bull. Soc. chim. France*, 1948, 708) might afford an androgen. In view of the ready elimination of the hydroxyl group under the conditions of the reduction leading to the ketone (IV) the more readily accessible ester (X) was reduced with an excess of sodium, liquid ammonia, and ethanol; as expected, after hydrolysis of the initial product, the ketone (XI) was obtained, nuclear reduction, Bouveault–Blanc reduction, and reductive elimination of the hydroxyl group occurring during the reaction. The ester (X) with an excess of methylmagnesium iodide gave what is believed to be the diol (XII), which could not be isolated and purified without dehydration : reduction, hydrolysis, and distillation of the unpurified material caused extensive dehydration.

Attempted angular methylation of the ester (XIII) by Birch and Robinson's method (*J.*, 1944, 501) afforded only intractable tars. Condensation with methylmagnesium iodide gave a mixture of the diol (XIV; R = Me) and a substance having the composition of a monodehydrated derivative of this, whilst reduction of the ester with lithium aluminium

hydride yielded the alcohol (XIV; R = H). Reduction of the diol (XIV; R = Me) with sodium and liquid ammonia gave the enol ether (XV) by the hydrolysis of which the keto-alcohol (XVI; R = Me) was prepared; a second, further reduced compound was also obtained, and this on hydrolysis yielded the hydroxy-ketone (XVII). Reduction of the simpler diol (XIV; R = H) with sodium and ammonia similarly gave, after hydrolysis, the ketone (XVI; R = H).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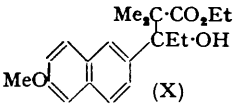
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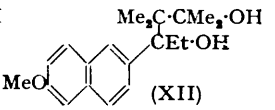
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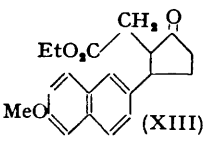
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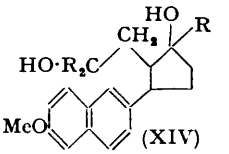
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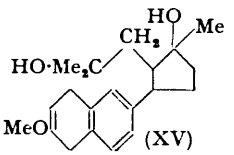
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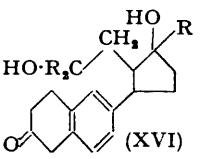
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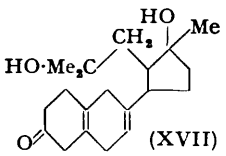
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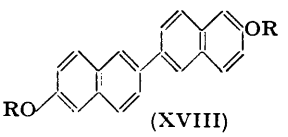
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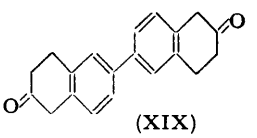
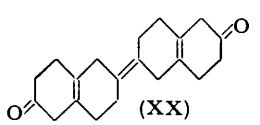

(XIX)

Derivatives of 6 : 6′-dihydroxy-2 : 2′-dinaphthyl (XVIII; R = H) were prepared with the intention of reducing these to the corresponding diketone (XX). The dihydroxydinaphthyl (XVIII; R = H), its dimethyl ether (XVIII; R = Me) and its di-2-hydroxyethyl ether (XVIII; R = CH_2·CH_2·OH) were all prepared by the reduction of 6-bromo-2-naphthol and its ethers by Busch's method (*Ber.*, 1929, **62**, 2612) modified so as to be conveniently carried out under normal pressure. The yields of bimolecular compounds were about 10%. The dimethyl ether (XVIII; R = Me) was too sparingly soluble in all solvents, and the diglyceryl ether [XVIII; R = CH_2·$CH(OH)$·CH_2·OH] was finally reduced in poor yield with an excess of sodium and liquid ammonia, with triethylene glycol (the only alcohol in which the ether was noticeably soluble even at high temperatures) as the reducing alcohol. The initial reduction product was evidently more soluble in this medium than the starting material, and apparently underwent considerable further reduction, as the product after hydrolysis gave analytical data in accord with the structure (XX) This product was a glass and isomerisation to the αβ-unsaturated ketone, involving the production of a mixture of isomers, may well have accompanied hydrolysis. The reduction of 6-bromo-2-methoxynaphthalene and of 6-acetyl-1-chloro-2-methoxynaphthalene with sodium and ammonia resulted in the loss of the halogen, so that reduction in this way before the bimolecular coupling is not practicable.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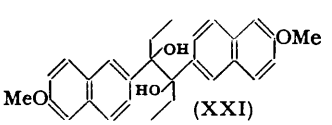
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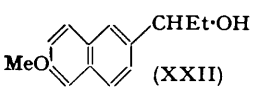
(XXII)

An attempt was made to prepare the naphthalene analogue of hexœstrol, and in this connection 6-methoxy-2-propionylnaphthalene was reduced in 10% yield to the pinacol (XXI), dehydration of which yielded only intractable material. In an attempt to prepare the naphthalene analogue of anethole in order to repeat with this substance Kharasch and Kleimann's hexœstrol synthesis (*J. Amer. Chem. Soc.*, 1943, **65**, 491) the alcohol (XXII) was heated with acetic anhydride: the acetyl ester was obtained, but with formic acid or anhydrous cupric sulphate, only polymers resulted.

Owing to the unsatisfactory nature of all these results [the substances (XI), (XVI; R = Me), (XVI; R = H), and (XX) proved to be androgenically inactive] these reactions were abandoned and investigation turned to the lines described in the following paper.

Experimental

2-1'-Hydroxyethyl-6-methoxynaphthalene.—A mixture of 2-acetyl-6-methoxynaphthalene (20 g.), aluminium *iso*propoxide (60 g.), and *iso*propyl alcohol was boiled under a fractionating column, with slow distillation until the distillate no longer gave a precipitate with 2 : 4-dinitrophenylhydrazine in aqueous acid. The mixture was then poured with stirring into excess of dilute hydrochloric acid containing ice, and the precipitate collected, washed, and dried (yield 16 g.). On recrystallisation light from petroleum (b. p. 80—100°)–benzene, *2-1'-hydroxyethyl-6-methoxynaphthalene* was obtained as colourless needles, m. p. 112° (Found : C, 77·6; H, 7·0. $C_{13}H_{14}O_2$ requires C, 77·2; H, 7·0%).

1 : *4-Dihydro-6-1'-hydroxyethyl-2-methoxynaphthalene* (V).—2-1'-Hydroxyethyl-6-methoxynaphthalene (10 g.) in ethanol (100 ml.) was added with vigorous stirring, followed by thin slices of sodium (1·8 g.), to liquid ammonia (500 ml.). Then the mixture was poured into water (500 ml.) and extracted with ether, and the extracts were dried and evaporated. The residue (8 g.), on recrystallisation from light petroleum (b. p. 60—80°), gave 1 : *4-dihydro-6-1'-hydroxyethyl-2-methoxynaphthalene* as plates, m. p. 87° (Found : C, 76·5; H, 7·5. $C_{13}H_{16}O_2$ requires C, 76·4; H, 7·8%).

For the hydrolysis 5 g. of the enol ether were shaken with 10% hydrochloric acid (100 ml.) at 40° for 1 hr., and the product extracted with ether. The residue on drying and evaporation of the ether was distilled (b. p. 116°/0·05 mm.) (Found : C, 81·2; H, 7·6. $C_{12}H_{14}O_2$ requires C, 80·0; H, 7·8. $C_{12}H_{12}O$ requires C, 83·6; H, 7·0%). It had a CO absorption band at 5·84 μ, and gave a yellow oily dinitrophenylhydrazone.

6-Ethyl-1 : 2 : 3 : 4 : 5 : 8-hexahydro-2-oxonaphthalene (IV).—2-1'-Hydroxyethyl-6-methoxynaphthalene (10 g.) was reduced as above with sodium (5·8 g.), liquid ammonia (350 ml.), and ethanol (100 ml.), the product isolated with ether, the ether evaporated, and the residue warmed for 30 min. with ethanol (25 ml.) and 10% hydrochloric acid (25 ml.). The mixture was poured into water, and the oil extracted with ether. After evaporation of the ether the residual oil was distilled, giving *6-ethyl-1 : 2 : 3 : 4 : 5 : 8-hexahydro-2-oxonaphthalene*, b. p. 162°/17 mm. (Found : C, 81·2; H, 9·1. $C_{12}H_{16}O$ requires C, 81·8; H, 9·1%). It had a CO absorption band at 5·85 μ and gave a yellow oily dinitrophenylhydrazone that became red in hot alcoholic sulphuric acid.

Ethyl 6-Methoxy-5-methyl-2-naphthoate.—6-Methoxy-5-methyl-2-naphthoic acid (12 g.), ethanol (200 ml.), and concentrated sulphuric acid (5 ml.) were boiled under reflux for 10 hr., then poured into water, and the *ester* was isolated by ether-extraction. It formed plates, m. p. 99—100°, from ethanol (Found : C, 73·6; H, 6·6. $C_{15}H_{16}O_3$ requires C, 73·6; H, 6·55%).

1 : 2 : 3 : *4-Tetrahydro-2-hydroxymethyl-6-methoxy-5-methylnaphthalene* (VIII).—Sodium (9·5 g.) was added in thin slices to a solution of ethyl 6-methoxy-5-methyl-2-naphthoate (10 g.) in liquid ammonia (500 ml.) and dry ethanol (150 ml.). The solution rapidly became yellow. When the sodium had dissolved the mixture was poured into water (500 ml.), and the product extracted with ether. Removal of the ether and recrystallisation of the residue from light petroleum (b. p. 60—80°) gave *2-hydroxymethyl-5-methyl-1 : 2 : 3 : 4-tetrahydronaphthalene*, prisms, m. p. 87° (Found : C, 75·4; H, 8·7. $C_{13}H_{18}O_2$ requires C, 75·6; H, 8·7%), which showed no CO band in the infrared region, but a OH band at 3·05 μ. This substance was recovered unchanged after prolonged boiling with alcoholic sodium hydroxide, and gave no trace of ketonic material on prolonged boiling with dilute hydrochloric acid.

6-(1-Ethyl-3-hydroxy-2 : 2-dimethyl)propyl-1 : 2 : 3 : 4-tetrahydro-2-oxonaphthalene (XI).—Ethyl 3-hydroxy-3-6'-methoxynaphthyl-2 : 2-dimethylpentanoate (X) (25 g.) in dry ethanol (150 ml.) was added, followed by sodium (14·5 g.), to liquid ammonia (750 ml.) with vigorous stirring. After the reduction the mixture was poured into water, the product extracted with ether, the extract evaporated, and the residue warmed at 50° for 30 min. with 10% alcoholic hydrochloric acid. This mixture was poured into water, the product extracted with ether, and the ether evaporated. The residue was then boiled under reflux with methanol (200 ml.), acetic acid (10 ml.), and Girard's reagent P (25 g.) for 2 hr., the mixture poured into dilute sodium hydroxide solution until the mixture was just alkaline to litmus, the non-ketonic matter removed by four extractions with ether, and the aqueous solution heated on the water-bath for 1½ hr. after acidification with hydrochloric acid. The mixture was finally cooled, and the product extracted with ether. The ether extracts on evaporation afforded a dark brown oil that was purified by distillation, giving pale brown *hydroxy-ketone* (2·5 g.), b. p. 180°/0·03 mm. (Found : C, 78·6; H, 9·6. $C_{17}H_{24}O_2$ requires C, 78·4; H, 9·3%).

Condensation of the Ester (X) *with Methylmagnesium Iodide.*—The ester (25 g.) and excess of methylmagnesium iodide (from 10 g. of magnesium) were heated in benzene (190 ml.)–ether

(40 ml.) for 8 hr., the mixture was cooled and acidified with ice and hydrochloric acid, and the benzene layer separated. Drying of the benzene solution, evaporation, and recrystallisation from light petroleum (b. p. 40—60°) and from ethanol gave a mixture as prisms, m. p. 87° (Found : C, 84·4; H, 7·6. Calc. for $C_{20}H_{26}O_2$: C, 80·5; H, 8·7. Calc. for $C_{20}H_{24}O$: C, 85·6; H, 8·6%).

When this product was reduced by sodium and liquid ammonia and the product distilled, visible dehydration and decomposition rapidly took place.

2-(2-*Hydroxy*-2-*methylpropyl*)-3-(6-*methoxy*-2-*naphthyl*)-1-*methyl*cyclo*pentanol* (XIV; R = Me).—Ethyl 2-(6-methoxy-2-naphthyl)-5-oxo*cyclo*pentyl acetate (10 g.) and excess of methylmagnesium iodide were heated under reflux in ether (250 ml.) for 5 hr., the mixture was decomposed by ice and hydrochloric acid, and the ether layer removed. The ether solution after drying and evaporation yielded a viscous oil that partly crystallised. This was shaken with benzene, and the solid was collected and recrystallised from methanol yielding 2-(2-*hydroxy*-2-*methylpropyl*)-3-(6-*methoxy*-2-*naphthyl*)-1-*methyl*cyclo*pentanol* as prisms, m. p. 147° (Found : C, 76·5; H, 8·8. $C_{21}H_{28}O_3$ requires C, 76·7; H, 8·5%). The benzene solution, on evaporation and distillation, yielded a pale brown *substance*, b. p. 160°/0·024 mm. (Found : C, 81·8; H, 8·5. $C_{21}H_{26}O_2$ requires C, 81·4; H, 8·4%), evidently a monodehydrated derivative of (XIV; R = Me).

2-2′-*Hydroxyethyl*-3-(6-*methoxy*-2-*naphthyl*)cyclo*pentanol* (XIV; R = H).—Ethyl 2-(6-methoxy-2-naphthyl)-6-oxo*cyclo*pentylacetate (15 g.) and excess of lithium aluminium hydride were heated under reflux in dry ether for 1 hr., the mixture was decomposed by dilute hydrochloric acid, and the ether layer evaporated, affording crystals that, recrystallised from benzene–light petroleum (b. p. 60—80°), gave 2-2′-*hydroxyethyl*-3-(6-*methoxy*-2-*naphthyl*)cyclo*pentanol*, prisms (12 g.), m. p. 130° (Found : C, 75·5; H, 7·7. $C_{18}H_{22}O_3$ requires C, 75·5; H, 7·7%).

2-(2-*Hydroxy*-2-*methylpropyl*)-3-(5 : 6 : 7 : 8-*tetrahydro*-6-*oxo*-2-*naphthyl*)-1-*methyl*cyclo*pentanol* (XVI; R = Me).—The alcohol (XIV; R = Me) (10 g.) was reduced with sodium (4 g.), liquid ammonia (400 ml.), and ethanol (150 ml.), and the product isolated with ether. The ether extract was shaken for 5 hr. with dilute hydrochloric acid, washed with water, and dried. On evaporation the residue crystallised in part and was shaken with light petroleum (b. p. 40—60°), and the solid collected and recrystallised from benzene–light petroleum (b. p. 60—80°), giving the *keto-alcohol* as prisms, m. p. 133—134° (Found : C, 75·9; H, 8·9. $C_{20}H_{28}O_3$ requires C, 75·9; H, 8·9%). This had a CO absorption band at 5·82 μ and a OH band at 3·1 μ.

The extract obtained by shaking the crude product with light petroleum was evaporated to dryness and the viscous residue distilled. 2-(2-*Hydroxy*-2-*methylpropyl*)-3-(1 : 4 : 5 : 6 : 7 : 8-*hexahydro*-6-*oxo*-2-*naphthyl*)-1-*methyl*cyclo*pentanol* (XVII) was obtained as a very pale brown oil, b. p. 210°/0·05 mm. (Found : C, 75·1; H, 9·1. $C_{20}H_{30}O_3$ requires C, 75·4; H, 9·4%).

2-2′-*Hydroxyethyl*-3-(5 : 6 : 7 : 8-*tetrahydro*-6-*oxo*-2-*naphthyl*)cyclo*pentanol* (XVI; R = H).—The ketone (XIV; R = H) (10 g.) was reduced with sodium (3 g.), ammonia (250 ml.), and ethanol (250 ml.), and the product isolated as before. After hydrolysis of the extract by shaking it with hydrochloric acid for 5 hr. and distillation, the 3-*hydroxy*-*ketone* was obtained as an almost colourless oil, b. p. 185—190°/0·05 mm. (Found : C, 75·3; H, 7·9. $C_{17}H_{22}O_3$ requires C, 74·8; H, 7·9%).

6 : 6′-*Dihydroxy*-2 : 2′-*dinaphthyl* (XVIII; R = H).—6-Bromo-2-naphthol (10 g.), a 5% 2-ethoxyethanol solution of potassium hydroxide (100 ml.), and 4% palladised strontium carbonate (5 g.) were heated at 135—140° under reflux with vigorous stirring, and 100% hydrazine hydrate (1·2 g.) was added. The mixture was boiled under reflux for 1 hr., cooled, filtered, acidified with hydrochloric acid, heated to the b. p., and diluted with water to incipient precipitation, then allowed to cool. 6 : 6′-*Dihydroxy*-2 : 2′-*dinaphthyl* separated as pale brown plates, which recrystallised from a large volume of 2-ethoxyethanol as fawn-coloured plates, m. p. 297—298° (Found : C, 83·4; H, 4·9. $C_{20}H_{14}O_2$ requires C, 83·8; H, 4·9%), readily soluble in alkalis and giving a green colour with ferric chloride.

6 : 6′-*Dimethoxy*-2 : 2′-*dinaphthyl* (XVIII; R = Me).—6-Bromo-2-methoxynaphthalene (10 g.) was reduced with hydrazine hydrate (1·2 g.; 100%), 5% 2-ethoxyethanolic potassium hydroxide (100 ml.), and palladised strontium carbonate (5 g.) as above. The solid matter was collected and boiled with nitrobenzene (50 ml.), and the solution filtered whilst hot. The filtrate on cooling deposited a quantity of almost colourless 6 : 6′-*dimethoxy*-2 : 2′-*dinaphthyl* (0·9 g.), plates, m. p. 289° (from nitrobenzene) (Found : C, 83·3; H, 6·0. $C_{22}H_{18}O_2$ requires C, 83·0; H, 5·8%), very sparingly soluble in the usual solvents.

6 : 6′-*Di*-(2-*hydroxyethoxy*)-2 : 2′-*dinaphthyl* (XVIII; R = $CH_2{\cdot}CH_2{\cdot}OH$). 2-Bromo-6-2′-hydroxyethoxynaphthalene (see below) (10 g.) was reduced as above. The solid deposited from

the mixture on cooling was extracted with boiling ethylene chlorohydrin; 6 : 6′-*di*-(2-*hydroxyethoxy*)-2-2′-*dinaphthyl* separated from the filtrate and formed plates, m. p. 280°, on recrystallisation from ethylene chlorohydrin (Found : C, 77·5; H, 6·2. $C_{24}H_{22}O_4$ requires C, 77·0; H, 5·9%).

6 : 6′-*Di*-(2 : 3-*dihydroxypropoxy*)-2 : 2′-*dinaphthyl* [XVIII; R = CH_2·CH(OH)·CH_2·OH)].—6 : 6′-Dihydroxy-2 : 2′-dinaphthyl (10 g.) was dissolved in alkali and heated on the water-bath with glycerol α-chlorohydrin (10 g.) until no further precipitate was formed. The crystalline solid was then collected and a sample recrystallised from diethylene glycol, giving the *ether* as plates (10 g.), m. p. 319° (Found : C, 71·4; H, 6·0. $C_{26}H_{26}O_6$ requires C, 71·8; H, 5·9%).

Reduction. The ether (10 g.) in hot triethylene glycol (400 ml.) was added slowly to a solution of sodium (25 g.) in liquid ammonia (1·5 l.) with vigorous stirring. When all the sodium had reacted the mixture was poured into water (2 l.), and the solid collected and shaken with ethyl acetate (150 ml.) and 2N-hydrochloric acid (200 ml.) until no further diminution in the amount of undissolved solid was noticed. The ethyl acetate layer was separated, washed with water, dried, and evaporated. The residue failed to crystallise, was dissolved in ethyl acetate, and passed through a column of activated alumina. The eluate from the column yielded 1·5 g. of a brown oil that was distilled, giving a pale brown oily *diketone* (? XX), b. p. 250°/0·001 mm. (Found : C, 81·1; H, 8·6. $C_{20}H_{24}O_2$ requires C, 81·1; H, 8·1%). This substance gave a red 2 : 4-dinitrophenylhydrazone that could not be purified.

2-*Bromo*-6-2′-*hydroxyethoxynaphthalene*.—6-Bromo-2-naphthol (10 g.) was heated on the water-bath with 10% aqueous potassium hydroxide (50 ml.) and ethylene chlorohydrin (10 g.) for 1 hr., then cooled. The *ether* was obtained as plates, m. p. 110°, from 60% acetic acid (Found : C, 56·2; H, 4·5; Br, 30·0. $C_{12}H_{11}OBr,H_2O$ requires C, 56·6; H, 4·9; Br, 30·4%).

Reduction. This ether (10 g.) was reduced with sodium (5 g.), liquid ammonia (400 ml.) and ethanol (50 ml.). The product was isolated by ether-extraction and hydrolysed with dilute hydrochloric acid and ethanol. The product was β-tetralone, which was purified by distillation (b. p. 135°/15 mm.) (Found : C, 81·6; H, 7·2; Br, 0·0. Calc. for $C_{10}H_{10}O$: C, 82·0; H, 6·9%).

Reduction of 6-*Acetyl*-1-*chloro*-2-*methoxynaphthalene*.—6-Acetyl-1-chloro-2-methoxynaphthalene (20 g.) was reduced by sodium (18 g.), liquid ammonia (600 ml.), and ethanol (100 ml.), and the product hydrolysed with alcoholic hydrochloric acid to an amber-coloured oil that was purified by distillation. 6-Ethyl-1 : 2 : 3 : 4 : 5 : 8-hexahydro-2-oxonaphthalene was obtained as colourless oil, b. p. 160°/17 mm. (Found : C, 80·9; H, 8·9. Calc. for $C_{12}H_{16}O$: C, 81·8; H, 9·1%).

3 : 4-*Di*-(6-*methoxy*-2-*naphthyl*)*hexane*-3 : 4-*diol* (XXI).—2-Methoxy-6-propionylnaphthalene (10 g.), absolute ethanol (100 ml.), dry sulphur-free benzene (75 ml.), freshly scoured aluminium foil (6 g.), and powdered mercuric chloride (0·25 g.) were heated on a water-bath for 15 hr.; by then all the aluminium had dissolved. The mixture was cooled, acidified with excess of ice-cold hydrochloric acid, and extracted with ether. The extract afforded, on evaporation, a brown gum, which was triturated with dilute acetic acid. Solid which separated was collected (1·1 g.) and recrystallised from 2-ethoxyethanol, giving the *diol* as prisms, m. p. 205° (Found : C, 78·3; H, 7·0. $C_{28}H_{30}O_4$ requires C, 78·1; H, 7·0%). Dehydration of this pinacol with acetic anhydride and acetyl chloride yielded intractable products.

2-1′-*Hydroxypropyl*-6-*methoxynaphthalene*.—2-Methoxy-6-propionylnaphthalene (25 g.) was heated with aluminium *iso*propoxide (25 g.) and *iso*propyl alcohol (250 ml.) with slow distillation, until the distillate no longer contained acetone. The mixture was then poured with stirring into ice and hydrochloric acid, and the precipitate collected and recrystallised from benzene–light petroleum (b. p. 60—80°); 2-1′-*hydroxypropyl*-6-*methoxynaphthalene* was obtained as plates, m. p. 87° (Found : C, 77·5; H, 7·6. $C_{14}H_{16}O_2$ requires C, 77·8; H, 7·4%). The *acetate*, prepared by refluxing acetic anhydride, formed plates, m. p. 65°, from light petroleum (b. p. 60—80°) (Found : C, 75·1; H, 7·3. $C_{16}H_{18}O_3$ requires C, 74·3; H, 7·0%).

Attempts to dehydrate the alcohol by heating it with formic acid, iodine, or anhydrous cupric sulphate gave only polymerised compounds.

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