amine and a solution of 1 g of potassium bicarbonate in 5 ml of water. The mixture was heated under reflux for 2 hr. On cooling, IV crystallized from the reaction mixture in slightly yellow plates (1.8 g). Recrystallization from methylene chloride–methanol yielded a pure sample: mp 242–244°; $[\alpha]_D$ +68.3°; λ_{max} 239, 263, and 321 mμ (log ε 4.503, 3.339, and 4.074).

Anal. Calcd for $C_{27}H_{34}N_2O_2$: C, 77.55; H, 8.11; N, 6.69. Found: C, 77.53; H, 8.32; N, 6.52.

Preparation of the Dioxime Derivative V.—A solution of 1 g of II in 50 ml of methanol was treated with a solution of 2 g of hydroxylamine acetate in 10 ml of methanol. After a few minutes of heating on the steam bath the dioxime V precipitated in fine needles, mp 272.5–275° dec, $[\alpha]_D$ +57.4 (pyridine).

Anal. Calcd for $C_{21}H_{32}N_2O_4$: C, 67.00; H, 8.58; N, 7.43. Found: C, 67.54; H, 8.35; N, 8.01.

3,17β-Diacetoxy-5α-androst-3-en-2-one (VIIb).—To a solution of 15 g of 17β-acetoxy-5α-androstan-3-one in 300 ml of alcohol there was added 120 g of selenium dioxide dissolved in 70 ml of water and 300 ml of alcohol. The mixture was heated under reflux for 15 min and then cooled. The precipitated selenium was removed by filtration and the filtrate was diluted with 1 l. of ether. The organic layer was washed first with 1 l. of a concentrated salt solution and then with 500 ml of a concentrated solution of sodium bicarbonate. The potassium salt of the diosphenol (VIIa) precipitated at the interface by shaking the etheral layer with 300 ml of 20% aqueous potassium hydroxide.

The resinous, dark precipitate was separated from the liquid layers and washed thoroughly with ether. The free diosphenol was liberated from its potassium salt by treatment with dilute hydrochloric acid followed by extraction with ether. The organic layer was washed with water, dried, and decolorized with activated charcoal. Upon concentration of the ether solution the diosphenol was crystallized in small, yellow plates. Recrystallization from ether yielded 3.5 g of pure VIIa: mp 151.5–153°, $[\alpha]_D$ +80.5°, λ_{max} 272 mμ (log ε 3.753).

Anal. Calcd for $C_{21}H_{30}O_4$: C, 72.81; H, 8.73. Found: C, 72.99; H, 8.58.

Treatment of the diosphenol VIIa with *o*-phenylenediamine and hydroxylamine acetate afforded the quinoxaline (mp 242–244°) and dioxime (mp 272.5–275°), respectively, which were identical in all respects with the corresponding derivatives obtained from II.

The enol acetate VIIb was prepared from the diosphenol by dissolving the latter in acetic anhydride and pyridine at room temperature. After standing for 24 hr the reaction mixture was worked up in the usual way. Crystallization from methanal yielded well-formed prisms: mp 184–184.5°; $[\alpha]_D$ +82.4°; λ_{max} 240 mμ (log ε 3.898); ν_{max} 2900, 1770, 1730, 1640, 1375, 1250, 1155, 1135, and 1065 cm^{-1}.

Anal. Calcd for $C_{23}H_{32}O_5$: C, 71.10; H, 8.30. Found: C, 70.78; H, 8.22.

The Synthesis of Nitrogen-Containing Steroids. I. Diels–Alder Adducts of Steroids and 4-Phenyl-1,2,4-triazoline-3,5-dione[1]

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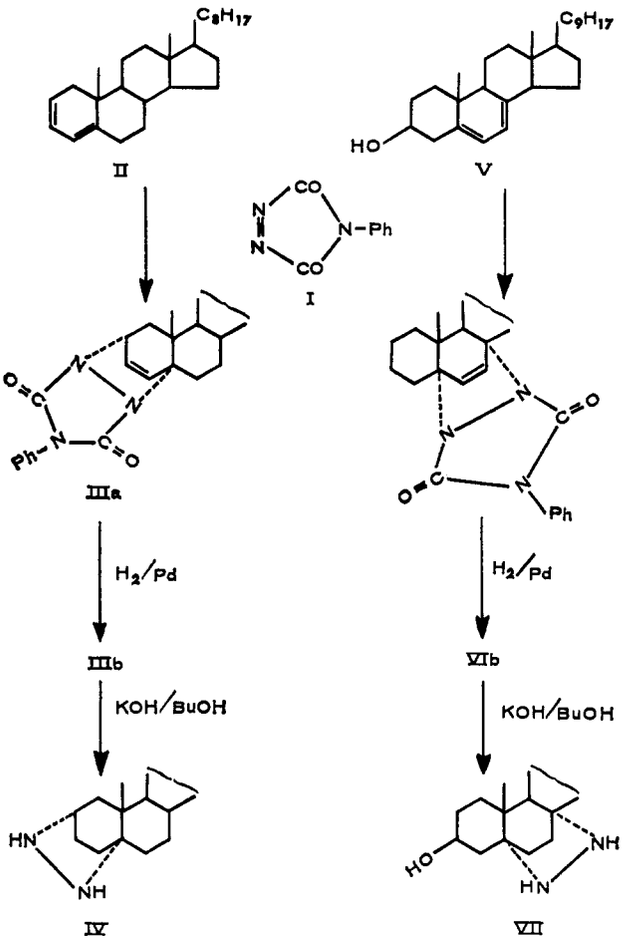
As part of a general program for the investigation of nitrogen-containing steroids, we have investigated the incorporation of azo and hydrazo bridges into rings A and B of $\Delta^{2,4}$-cholestadiene (II) and ergosterol (V). respectively, by the use of the dienophilic reagent 4-phenyl-1,2,4-triazoline-3,5-dione (I) (see Scheme I), Despite reports that the Diels–Alder reaction between

SCHEME I



ergosterol and maleic anhydride is slow[2] and that hydrogen abstraction–addition constitutes an undesirable side reaction in the ergosterol–ethyl diazocarboxylate reaction,[3] it was hoped that I would behave normally on the basis of its reactivity in various systems[4] including steroids.[5]

I reacted instantly with $\Delta^{2,4}$-cholestadiene in acetone–benzene solution at 0° as shown by disappearance of the red color of I. The adduct IIIa was isolated and characterized as such by several lines of evidence: the diene ultraviolet absorption pattern of II (λ_{max} 275 and 267 mμ) had disappeared; in the infrared spectrum, a carbonyl doublet at 1705 and 1760 cm^{-1} typical of adducts of I[4,5] had appeared; the pmr spectrum showed peaks at δ 6.25 and 6.34 (doublet integrating for two protons, J = 4 cps) assigned to ring A vinyl protons and a singlet at δ 7.4 assigned to N-phenyl; and finally, absence of NH peaks in the infrared spectrum and elemental analysis lend strong support to structure IIIa.

The adduct IIIa was hydrogenated at 3-atm pressure (5% Pd–C) to give the dihydro adduct IIIb which was isolated and characterized by analysis, absence of peaks for vinyl protons at δ 6.25 and 6.34 in the pmr spectrum, and the presence of the N-phenyl peak at δ 7.4. Hy-

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drolysis of IIIb with 2 *N* potassium hydroxide in butan-1-ol (43 hr) gave the hydrazine IV in good yield as evidenced by absence of carbonyl peaks and appearance of NH peaks in the infrared spectrum, absence of N-phenyl peaks at δ 7.4 in the pmr spectrum, satisfactory elemental analysis, and the trapping of the aniline formed in the hydrolysis as diphenylurea.

I also reacted instantly with ergosterol (V) in acetone–benzene solution at 0° as shown by disappearance of the color of I. The adduct VIa was characterized by the disappearance of the ring-diene absorption pattern for ergosterol at λ_{max} 282 mμ, appearance of a carbonyl doublet at 1675 and 1735 cm^{-1}, and the pmr spectrum which showed peaks at δ 7.4 (N-phenyl), 5.2 and 5.26 (multiplet, integrating for the two vinyl protons at C-22 that were in the same position in ergosterol), and 6.24 and 6.33 (two vinyl protons at C-6 and C-7, J = 4 cps). No hydrogen abstraction–addition product[3] could be isolated.

The adduct VIa was hydrogenated to the tetrahydro adduct VIb, whose pmr spectrum failed to reveal vinylic protons. Hydrolysis of VIb to the hydrazine VII required more drastic conditions compared to IIIb, namely, 120-hr reflux in 3 *N* potassium hydroxide in butan-1-ol. VII was characterized by absence of the N-phenyl peak in the pmr spectrum, by the absence of a carbonyl doublet and the presence of NH peaks in the infrared spectrum, and by elemental analysis.

It has been established that adduct formation in rings A and B of $\Delta^{2,4}$-cholestadiene and ergosterol takes place from the less hindered α side[6] and we therefore assume that the stereochemistry of IIIa and VIa is as depicted.

Experimental Section[7]

$\Delta^{2,4}$-Cholestadiene (II).—The procedure of Stavely and Bergmann[8] was employed with some modification. A cholesterol–alumina (Fischer chromatographic grade) mixture (3:2) was heated for 2.5 hr at 225° (0.4 mm). The yellow mixture was cooled and extracted with methylene chloride, and the extracts were chromatographed (Woelm neutral alumina) using benzene as the eluent to give II in 64% yield: mp and mmp 60–62°.

Adduct IIIa of II with 4-Phenyl-1,2,4-triazoline-3,5-dione (I).—To a solution of II (0.368 g) in dry acetone (25 ml) and a little benzene (to homogeneity) was added dropwise at 0° a freshly prepared[3] solution of I in dry acetone until the reaction mixture remained pale pink. The reaction mixture was chromatographed (Woelm neutral alumina) using benzene and ethyl acetate (95:5) as eluent and recrystallized from ethanol to give IIIa (0.47 g, 90%): mp 200–204°; ν^{Nujol} 1705, 1760 cm^{-1} (C=O).

Anal. Calcd for $C_{35}H_{49}N_3O_2$: C, 77.30; H, 9.08; N, 7.7. Found: C, 77.3; H, 9.3; N, 7.4.

Catalytic Reduction of Adduct IIIa.—IIIa (0.9 g) in ethanol (100 ml) was hydrogenated for 19 hr at 45 psi with 5% Pd–C (300 mg). The solution was evaporated *in vacuo* and the solid material was chromatographed (Woelm neutral alumina) using benzene and ethyl acetate (95:5) as eluent and crystallized from ethanol to give IIIb in near quantitative yield: mp 208–209°; ν^{Nujol} 1705, 1760 cm^{-1} (C=O).

Anal. Calcd for $C_{35}H_{51}N_3O_2$: C, 77.00; H, 9.42; N, 7.7. Found: C, 77.26; H, 9.42; N, 7.4.

Alkaline Hydrolysis of Reduced Adduct IIIb.—IIIb (1.08 g) and potassium hydroxide–butan-1-ol (40 ml, 2 *N*) were refluxed in a nitrogen atmosphere for 43 hr. The solution was evaporated *in vacuo* and the solid material was extracted into methylene chloride, chromatographed (Woelm neutral alumina) using benzene and ethyl acetate (80:20) as eluent, and crystallized from ethanol–ether to give IV (0.439 g, 60%): mp 115–118°, ν^{Nujol} 3400 cm^{-1} (NH) (br).

Anal. Calcd for $C_{27}H_{48}N_2$: C, 80.91; H, 12.08; N, 6.99. Found: C, 80.97; H, 11.90; N, 6.93.

Adduct VIa of V and 4-Phenyl-1,2,4-triazoline-3,5-dione (I).—This was prepared in a similar manner to adduct IIIa from 0.8 g of ergosterol in acetone–benzene. The reaction mixture was evaporated under reduced pressure and crystallized three times from aqueous acetone to give VIa (0.93 g, 85%): mp 190–191.5°; ν^{Nujol} 1675, 1735 (C=O), 3450 cm^{-1} (OH).

Anal. Calcd for $C_{36}H_{49}N_3O_3$: C, 75.63; H, 8.64; N, 7.35. Found: C, 75.47; H, 8.77; N, 7.54.

Catalytic Reduction of Adduct VIa.—VIa (0.57 g) in ethanol (40 ml) was hydrogenated for 16 hr at 50 psi with 5% Pd-C (300 mg). The solution was evaporated under reduced pressure, chromatographed (Woelm neutral alumina) using benzene and ethyl acetate (95:5) as eluent, and crystallized from ethanol to give VIb (0.49 g, 86%): mp 178–182°; ν^{Nujol} 1675, 1740 (C=O), 3435 cm^{-1} (OH).

Anal. Calcd for $C_{36}H_{53}N_3O_3$: C, 75.1; H, 9.2; N, 7.3. Found: C, 74.89; H, 9.02; N, 6.8.

Alkaline Hyrolysis of Reduced Adduct VIb.—VIb (1.7 g) and potassium hydroxide–butan-1-ol (100 ml, 3 *N*) were refluxed in a nitrogen atmosphere for 120 hr and extracted as for adduct IIIb to give VII (0.3 g, 25%): mp 189–192°, ν^{Nujol} 3410 cm^{-1} (NH) (br).

Anal. Calcd for $C_{28}H_{50}N_2O$; C, 78.1; H, 11.6; N, 6.5. Found: C, 77.92; H, 11.66; N, 6.4.

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The Preparation of Triazines Related to 6-Cyano-2,2′-bipyridine[1]

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For the preparation of 6-cyano-2,2′-bipyridine,6-chloro- or -bromobipyridine was needed. The chloro compound was prepared by converting 2,2′-bipyridine methiodide by an alkaline oxidation with potassium ferricyanide to the hitherto unreported 1-methyl-2,2′-bipyridin-6-one and treating the latter with phosphoryl chloride and phosphorus pentachloride. However, since the halogen in this compound was too unreactive to yield the cyanobipyridine, 6-bromo-2,2′-bipyridine was prepared from the bipyridinone using phosphoryl bromide, phosphorus tribromide, and bromine. This compound had previously been prepared by direct vapor phase bromination of 2,2′-bipyridine.[2] The bromobipyridine was then converted smoothly to 6-cyano-2,2′-bipyridine by cuprous cyanide in pyridine. The melting point observed for the cyanobipyridine was considerably lower than that previously reported.[2]

Starting from 6-cyano-2,2′-bipyridine and using reactions previously described[3,4] for cyanopyridine

(1) This work was supported by a grant (G-9645) from the National Science Foundation.

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