New Steroidal Heterocycles: Synthesis and Structure of Androst-2-eno[2,3-*g*](tetrazolo[1,5-*a*]pyridimines), Androst-4-eno[3,2-*f*](tetrazolo-[1,5-*a*]pyrimidine), and Androstano[17,16-*f*](tetrazolo[1,5-*a*]pyrimidines)

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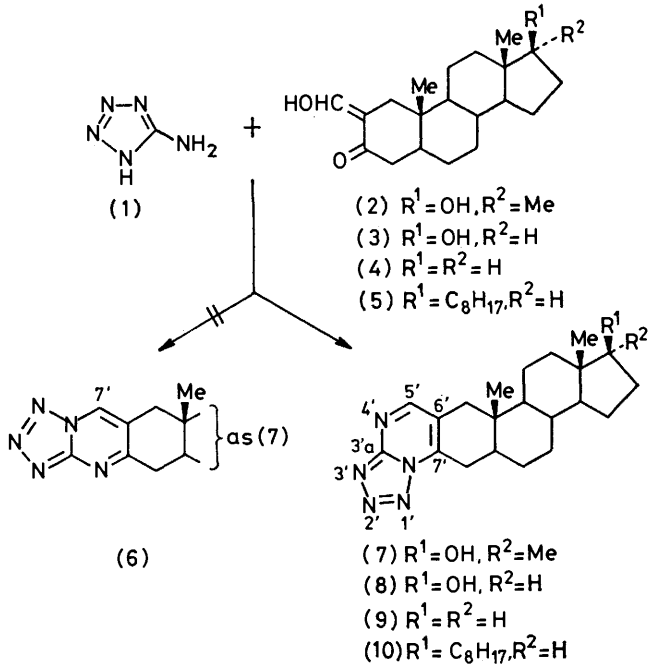
The condensation of 5-aminotetrazole (1) with 2-hydroxymethylene-3-oxosteroids [(2)—(5) and (16)] gave steroid-2-eno[2,3-*g*](tetrazolo[1,5-*a*]pyrimidines) [(7)—(10) and (17)]. However, the reaction of a 2-hydroxymethylene-Δ^4-3-oxosteroid (18) with 5-aminotetrazole (1) gave a product which exists predominantly in the form (19a) in which the tetrazolopyrimidine system is linearly fused to the steroid nucleus. During the acetylation of (19a) with acetic anhydride–pyridine, in addition to the expected 17β-acetoxy-derivative (21a), 17β-acetoxy-4-oxo-5ζ-androst-2-eno[2,3-*g*](tetrazolo[1,5-*a*]pyrimidine) (22a) was isolated. The reaction of 16-hydroxymethylene-17-oxosteroids (26) and (29) with 5-aminotetrazole (1) also gave the linearly fused tetrazolopyrimidines (27) and (30). All the tetrazolopyrimidines exist in the tetrazolo-form in dimethyl sulphoxide solution and in the solid state, whereas in bromoform and deuteriochloroform solutions the tetrazolo-isomers are found to be in equilibrium with small quantities of their corresponding azido-forms. The structures of all these products are elucidated with the help of u.v., i.r., ^{1}H n.m.r., and ^{13}C n.m.r. spectroscopy.

As a part of our studies directed towards the development of new aza-steroids of biological interest we have reported, in our previous communications,[1a-c] the condensation reactions of 2-amino-1,3,4-thiadiazole, 4-amino-1,2,4-triazole, 3-aminopyrazoles, 3-amino-1,2,4-triazoles, and 2-aminobenzimidazole with various steroidal β-ketoaldehydes. In this publication we report the results of the reaction of 5-aminotetrazole (1) with steroidal β-ketoaldehydes.



RESULTS AND DISCUSSION

The condensation of 5-aminotetrazole (1) with the unsymmetrical β-ketoaldehyde 17β-hydroxy-2-hydroxymethylene-17α-methyl-5α-androstan-3-one (2) can conceivably afford 17β-hydroxy-17α-methyl-5α-androstano-[3,2-*f*](tetrazolo[1,5-*a*]pyrimidine) (6) and/or 17β-hydroxy-17α-methyl-5α-androst-2-eno[2,3-*g*](tetrazolo-[1,5-*a*]pyrimidine) (7). However, when this condensation reaction is carried out in refluxing ethanol, only one product, in 84% yield, is isolated which is shown by spectroscopic evidence to have structure (7).

The ^{1}H n.m.r. spectrum of the condensation product (7) shows signals at δ 0.88 (s, 18-Me), 0.92 (s, 19-Me), 1.24 (s, 17-Me), and 8.67 (s, 5′-H). It is particularly noted that in the ^{1}H n.m.r. spectrum, the signal for the proton (5′-H) of the pyrimidine ring is found to be sharp and this is consistent with the structure (7) assigned to the condensation product. It has been previously reported in our recent publications [1c,d] that a small long-range coupling is observed between the pyrimidine ring-proton and the methylene protons at position 1 in the linearly fused azolo[1,5-*a*]pyrimidines (11). In contrast no such long-range coupling between the pyrimidine ring-proton and the methylene protons at position 1 is observed in the angularly fused azolo[1,5-*a*]pyrimidines (12). Therefore the alternative structure (6) is discounted, since the 7′-H would be expected to give a singlet broadened by a small long-range coupling with the methylene protons.

The assignment of structure (7) is further supported by ^{13}C n.m.r. evidence. The ^{13}C chemical shifts of the aromatic ring-carbons of the tetrazolopyrimidine (7) are given in the Table. The assignments quoted for the chemical shifts of the aromatic ring-carbons of the steroid (7) follow directly by analogy with the values allocated to the comparable ring system (13).[1f] The chemical shift of 5′-C (δ 159.79) in the condensation

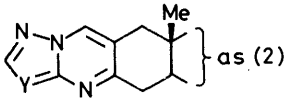
^{13}C Chemical shifts of steroidal tetrazolo[1,5-*a*]pyrimidines (δ from $SiMe_4$)

Compound	3′a-C	5′-C	6′-C	7′-C	Other carbons
(7)	154.17	159.79	120.92	142.76	
(13)	158.91	158.44	112.32	146.84	
(19a) *	154.77	167.64	120.78	129.54	4-C, 121.17; 5-C, 161.67
(24a)	153.06	176.81	128.93	126.12	

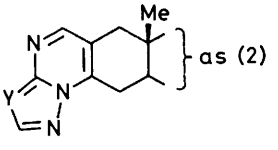
* Spectrum in [$^2H_6$]DMSO.

product (7) is found to be in agreement with the chemical shift of 5-C (δ 158.44) in 7-methyltetrazolo[1,5-*a*]pyrimidine (13) and 5′-C (δ 155.94) in 17β-hydroxy-17α-methyl-5α-androst-2-eno[2,3-*g*](*s*-triazolo[1,5-*a*]pyrimidine) (12; Y = N).[1d] This confirms the angular fusion of the steroid to the heterocyclic system. If the condensation product had had the linear structure (6), the chemical shift of 7′-C would have been expected to appear in the region of δ 133.77 which is the chemical shift of 7′-C in 17β-hydroxy-17α-methyl-5α-androstano-[3,2-*f*](*s*-triazolo[1,5-*a*]pyrimidine) (11; Y = N).[1d]

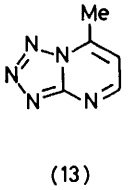
It is also noticed that the ^{1}H n.m.r. spectrum of the product (7) in deuteriated chloroform also contains a small signal at δ 8.20 in addition to the signal for the 5′-H at δ 8.66. The signal at δ 8.20 persists even after further recrystallisation of the product from ethanol. This shows that compound (7) exists in equilibrium with its azido-form (14) and this is confirmed by the i.r. spectrum of the compound in bromoform which exhibits a distinct azide absorption at 2 140 cm^{-1}. The i.r. spectrum of compound (7) in Nujol does not show any azide absorption band in the region of 2 100—2 200 cm^{-1} and the ^{1}H n.m.r. spectrum in [$^2H_6$]DMSO shows no other signal in the aromatic region apart from the signal at δ 8.60 which corresponds to 5′-H in the tetrazolo-form (7). These observations indicate that the condensation product exists solely in the tetrazolo-form (7) in [$^2H_6$]-DMSO and in the solid state. However, in $CDCl_3$ the tetrazolo-form (7) is found to be in equilibrium with a small amount of the azido-form (14). It is also observed that the chemical shift of the 5′-H (δ 8.60) in the tetrazolo-form (7) occurs at a lower field when compared with the chemical shift (δ 8.20) of the corresponding



(11) Y = CH or N



(12) Y = CH or N



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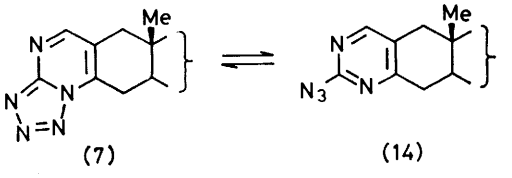
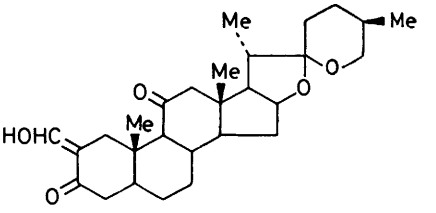


(7) (14)

proton (6′-H) in the azido-form (14). This difference is attributed [2] to the opposing effect of the electron-withdrawing tetrazole ring (deshielding) and the electron-donating azido-group (shielding). Rearrangements of this type have been recently demonstrated in several tetrazoloazine series through the simultaneous applications of i.r. and ^{1}H n.m.r. spectroscopy.[3] It has been shown that regardless of the tetrazoloazine (15) the tetrazolo-tautomer (15a) is generally favoured in the solid state or in dimethyl sulphoxide solution.[3-5]

(15a) (15b)

Under analogous reaction conditions, the condensation of 5-aminotetrazole (1) with 17β-hydroxy-2-hydroxymethylene-5α-androstan-3-one (3), 2-hydroxymethylene-5α-androstan-3-one (4), 2-hydroxymethylene-5α-



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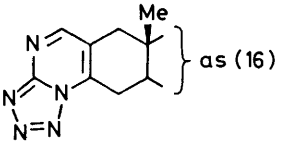
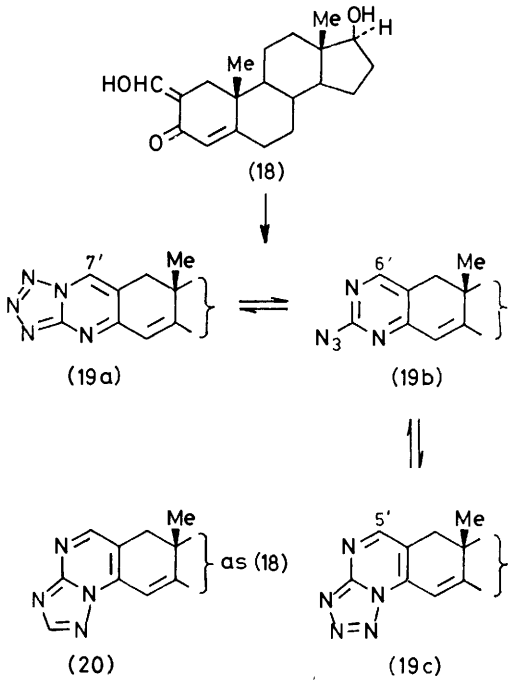


(17)

cholestan-3-one (5), and 2-hydroxymethylene-5α-spirostan-3,11-dione (16) gave 17β-hydroxy-5α-androst-2-eno[2,3-*g*](tetrazolo[1,5-*a*]pyrimidine) (8), 5α-androst-2-eno[2,3-*g*](tetrazolo[1,5-*a*]pyrimidine) (9), 5α-cholest-2-eno[2,3-*g*](tetrazolo[1,5-*a*]pyrimidine) (10), and 11-oxo-5α-spirost-2-eno[2,3-*g*](tetrazolo[1,5-*a*]pyrimidine) (17) respectively. These products also exist in equilibrium with their corresponding azido-forms in $CDCl_3$ or bromoform and in only their tetrazolo-forms in [$^2H_6$]DMSO and in the solid state.

The reaction of 5-aminotetrazole (1) with the 2-hydroxymethylene-Δ^4-3-oxosteroid (18), however, follows a different course leading to a product which exists predominantly in the form (19a). The i.r. spectrum of the product (19) in bromoform exhibits an absorption at 2 140 cm^{-1}, indicating the presence of the azido-tautomer (19b). The ^{1}H n.m.r. spectrum in $CDCl_3$ initially indicates the presence of only one compound which is characterised as (19a), since the signal at δ 8.60 corresponding to 7′-H is found to be broadened by a small long-range coupling with the methylene protons at position 1. After 10 min, however, two additional small signals, corresponding to the azido-isomer (19b) appear at δ 8.16 and δ 6.20. After 24 h this isomer reaches a concentration of about 40% as calculated from the ratio of the integrated intensities for the protons from the

tetrazolo-form (19a) to those of the azido-isomer (19b). The signals at δ 8.16 and δ 6.20 in the ^{1}H n.m.r. spectrum are assigned to the 6′-H and the 4-H respectively in the tautomer (19b). After 24 h, the third isomer (19c) is



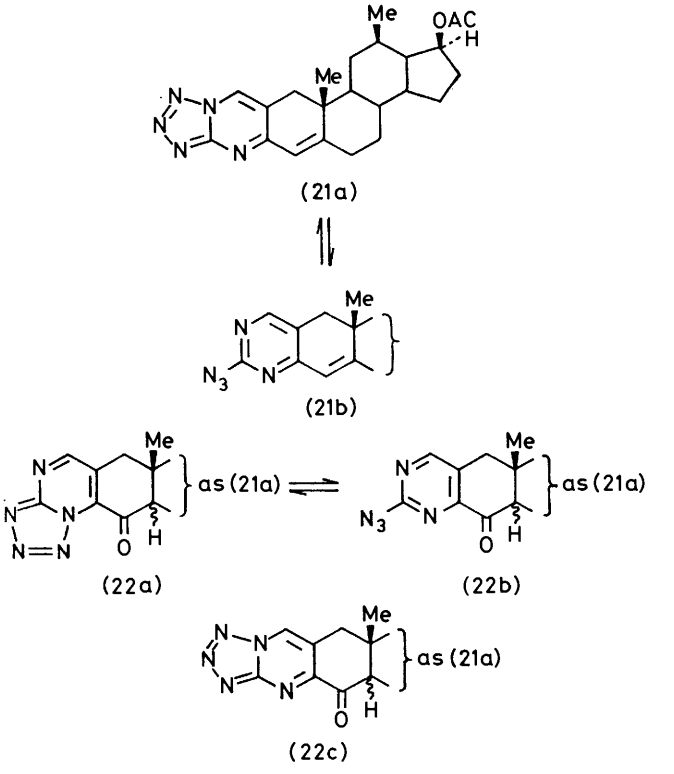
also found to be present (about 10%) in the ^{1}H n.m.r. sample tube and signals at δ 8.64 and δ 6.98 are assigned to the 5′-H and the 4-H respectively. The chemical shift of 4-H (δ 6.98) in the tautomer (19c) correlates well with the chemical shift of 4-H (δ 6.92) in 17β-hydroxyandrost-2,4-dieno[2,3-*g*](*s*-triazolo[1,5-*a*]pyrimidine) (20) [1d] and this supports the assignment of structure (19c).

In [$^2H_6$]DMSO, only one isomer is detected and this is characterised as (19a) by its ^{13}C n.m.r. spectrum where the chemical shift of the 7′-C (δ 129.53) is found to agree well with the value observed for the 8-C (δ 126.12) in 6,7-dihydro-5*H*-cyclopenta[*f*]tetrazolo[1,5-*a*]pyrimidine (24a), see Table.

Acetylation of 17β-hydroxyandrost-4-eno[3,2-*f*](tetrazolo[1,5-*a*]pyrimidine) (19a) with acetic anhydride in pyridine leads to the formation of two products (21) and (22). The i.r. and ^{1}H n.m.r. spectra obtained for the product (21a) resemble closely the i.r. and ^{1}H n.m.r. spectra for its precursor (19a), therefore this product is formulated as 17β-acetoxyandrost-4-eno[3,2-*f*](tetrazolo-[1,5-*a*]pyrimidine) (21a). The i.r. and ^{1}H n.m.r. spectra also indicates that the product (21a) exists in equilibrium with a small amount of the azido-tautomer (21b).

The molecular formula $C_{23}H_{29}N_5O_3$, obtained by mass spectrometry and elemental analysis, of the second product (22), shows that it differs from that of 17β-acetoxyandrost-4-eno[3,2-*f*](tetrazolo[1,5-*a*]pyrimidine) (21a) in having one extra oxygen atom, but this product still has the characteristic u.v. spectrum of the tetrazolo-[1,5-*a*]pyrimidine moiety (see Experimental section).

It therefore appears that this steroid is formed by the action of acetic anhydride–pyridine on the Δ^4 double bond of its precursor (21a). The i.r. spectrum of the steroid shows no absorption in the hydroxy-region but does exhibit two new absorptions at 1 720 and 1 685 cm^{-1}. The absorption at 1 720 cm^{-1} is assigned to the carbonyl of the 17β-acetoxy-group by analogy with 17β-acetoxyandrost-4-eno[3,2-*f*](tetrazolo[1,5-*a*]pyrimidine) (21a) and the absorption at 1 685 cm^{-1} is attributed to the presence of a new conjugated carbonyl group. Thus, it appears that the steroid has either structure (22a) or (22c). It has been noted in our previous publications [1c,d] that the number and shape of the absorption bands in the region 1 500—1 630 cm^{-1} of heterocyclic steroids are helpful in differentiating between linear or angular fusion of the heterocyclic system to the steroid nucleus. The absorptions at 1 625, 1 545, and 1 510 cm^{-1} in the i.r. spectrum of the steroid (22) differ significantly from the corresponding absorptions in the i.r. spectra of 17β-hydroxy- and 17β-acetoxy-androst-4-eno[3,2-*f*](tetrazolo-[1,5-*a*]pyrimidine) (19a) and (21a) but are identical with the absorptions in the i.r. spectrum of 17β-hydroxy-17α-methyl-5α-androst-2-eno[2,3-*g*](tetrazolo[1,5-*a*]pyrimidine) (7). Therefore, this steroid is formulated as 17β-acetoxy-4-oxo-5ζ-androst-2-eno[2,3-*g*](tetrazolo-[1,5-*a*]pyrimidine) (22a) and this structure is further supported by ^{1}H n.m.r. spectroscopy, where the signal



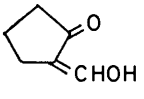
for the 5′-H is found to be sharp. If the product had had structure (22c), the signal for the 7′-H would have been broadened due to a small long-range coupling with the methylene protons at position 1.[1c,d] The i.r.

spectrum of the steroid (22a) in bromoform shows an azide absorption at 2 140 cm^{-1}, whilst the ^1H n.m.r. spectrum in $CDCl_3$ shows a small signal at δ 8.20 [6′-H in (22b)] suggesting that the product also exists in equilibrium with a small quantity of the azido-tautomer (22b).

In 1950, Cook *et al.*[6] reported that the condensation of 2-hydroxymethylenecyclopentanone (23) with 5-aminotetrazole leads to the formation of 7,8-dihydro-6*H*-cyclopenta[*g*]tetrazolo[1,5-*a*]pyrimidine (24c). The claim to this structure was presumably based upon the fact that the amino-group of the tetrazole (1) reacts first with the aldehyde group and then the direct cyclisation of the intermediate keto-anil gives the product (24c). This reaction has been repeated by us and it is now established with the aid of ^1H n.m.r. and ^{13}C n.m.r. spectroscopy that the product of this condensation has, on the contrary, the linear structure (24a).

In the ^1H n.m.r. spectrum of the product (24a) the signal at δ 8.72 corresponding to the 8-H is found to be split into a triplet by a small long-range coupling with the methylene protons at position 7. In the ^{13}C n.m.r. spectrum, the chemical shift of 8-C (δ 126.12) is found to closely resemble the chemical shift of 8-C (δ 129.61) in 6,7-dihydro-5*H*-cyclopenta[*f*]-*s*-triazolo[1,5-*a*]pyrimidine (25).[1f] If the product had had the previously reported structure (24c) then the signal for 5-H in the ^1H n.m.r. spectrum would have been a sharp singlet and the chemical shift of 5-C in the ^{13}C n.m.r. spectrum would have been in the region of δ 158.44 which is the chemical shift of 5-C of 7-methyltetrazolo[1,5-*a*]pyrimidine (13).[1b] The i.r. and ^1H n.m.r. spectrum also show that the product (24a) exists in equilibrium with the azido-form (24b) in bromoform and $CDCl_3$ solutions.

By analogy with the formation of 6,7-dihydro-5*H*-cyclopenta[*f*]tetrazolo[1,5-*a*]pyrimidine (24a) from the reaction of 5-aminotetrazole with 2-hydroxymethylenecyclopentanone (23), the products obtained by the



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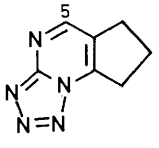
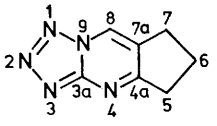
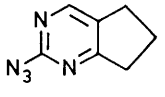


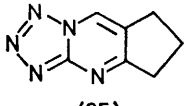
(24c)



(24a)



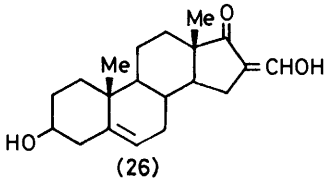
(24b)



(25)

condensation of 5-aminotetrazole with the β-keto-aldehydes (26) and (29) are assigned structures (27) and (30), respectively. The sterol (27) was acetylated using acetic anhydride–pyridine to give the 3β-acetate (28).

It is believed that the condensation reaction of 5-aminotetrazole (1) with steroidal β-ketoaldehydes proceeds through a mechanism similar to that outlined in our previous publication.[1b] However, it is impossible



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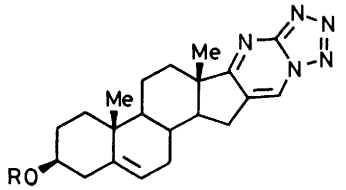
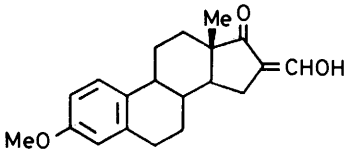


(27) R = H
(28) R = Ac



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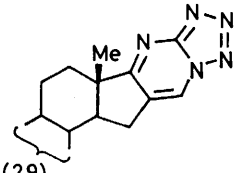

(30)

in this particular case to discriminate between pathway (a) and pathway (b); since each particular tetrazolopyrimidine could have been initially formed as either a linear or angularly fused product with subsequent interconversion *via* an intermediate azido-tautomer. It appears that the final structure of the condensation product is determined by the differences in π-strain associated with the different types of fusion of the pyrimidine ring system to the steroid. When the tetrazolopyrimidine ring system is fused to ring A of the steroid, only angular fusion is observed; when, however, fusion of the heterocyclic ring is to the steroid ring D, only linear fusion is observed.

EXPERIMENTAL

M.p.s were determined on Gallenkamp apparatus and are uncorrected. The u.v. spectra were taken in methanol on a Unicamp SP 800 spectrometer. I.r. spectra were recorded in bromoform, unless otherwise stated, on a Perkin-Elmer 157G spectrometer. ^1H N.m.r. spectra were recorded in $CDCl_3$ using $SiMe_4$ as an internal standard on Nuclear Magnetic Resonance Ltd. EM 360 (60 MHz) or Varian HA 100 (100 MHz) spectrometers. Mass spectro-

metry was carried out on an A.E.I. MS 902 instrument. ^{13}C N.m.r. spectra were obtained in $CDCl_3$, unless otherwise stated, on a Varian CFT-20 n.m.r. spectrometer operating at 20.80 MHz in the Fourier-transform mode at a probe temperature of 30 °C.

All the starting steroidal β-ketoaldehydes were prepared by known literature routes.

General Procedure for the Condensation Reactions.—A solution of the steroidal β-ketoaldehyde (1.5×10^{-3} mol) and 5-aminotetrazole (1) ($CH_3N_5 \cdot H_2O$, 2×10^{-3} mol) in absolute ethanol (30 ml) was refluxed overnight. The reaction mixture was cooled and triturated. The precipitates formed were filtered off and recrystallised from a suitable solvent.

17β-*Hydroxy*-17α-*methyl*-5α-*androst*-2-*eno*[2,3-g](*tetrazolo*-[1,6-a]*pyrimidine*) (7). This was recrystallised from methanol to give white crystals (84%), m.p. 196—198 °C; $\lambda_{max.}$ 216 and 280 nm (log ε 4.31 and 3.72); $\nu_{max.}$ 3 600 (OH), 2 140 (N_3), 1 620, 1 545, 1 510, 1 445, 1 380, 1 370, 930, and 780 cm^{-1} (Found: C, 69.05; H, 8.3; N, 18.2%; M^+, 381.251 944. $C_{22}H_{31}N_5O$ requires C, 69.24; H, 8.19; N, 18.36%; *M*, 381.252 847).

17β-*Hydroxy*-5α-*androst*-2-*eno*[2,3-g](*tetrazolo*[1,5-a]*pyrimidine*) (8). This was recrystallised from methanol to give white crystals (92%), m.p. 199—200 °C; $\lambda_{max.}$ 215 and 279 nm (log ε 4.29 and 3.73); $\nu_{max.}$ 3 600 (OH), 2 140 (N_3), 1 625, 1 545, 1 510, 1 385, 1 050, and 780 cm^{-1}; δ 0.80 (s, 3 H, 18-Me), 0.88 (s, 3 H, 19-Me), 3.68 (t, 1 H, 17-H), and 8.66 (s, 1 H, 5′-H) (Found: C, 68.7; H, 8.0; N, 19.25%; M^+, 367.235 799. $C_{21}H_{29}N_5O$ requires C, 68.62; H, 7.96; N, 19.06%; *M*, 367.237 198).

5α-*Androst*-2-*eno*[2,3-g](*tetrazolo*[1,5-a]*pyrimidine*) (9). This was recrystallised from ethanol to give yellow fluffy crystals (77%), m.p. 195—197 °C; $\lambda_{max.}$ 215, 248, and 280 nm (log ε 4.26, 3.73, and 3.63); $\nu_{max.}$ 2 130 (N_3), 1 625, 1 545, 1 505, 1 440, 1 420, 1 385, 820, and 780 cm^{-1}; δ 0.74 (s, 3 H, 18-Me), 0.86 (s, 3 H, 19-Me), and 8.66 (s, 1 H, 5′-H) (Found: C, 71.95; H, 8.5; N, 20.1%; M^+, 351.240 969. $C_{21}H_{29}N_5$ requires C, 71.75; H, 8.32; N, 19.93%; M^+, 351.242 281).

5α-*Cholest*-2-*eno*[2,3-g](*tetrazolo*[1,5-a]*pyrimidine*) (10). This was recrystallised from methanol to give white crystals (61%), m.p. 173—175 °C; $\lambda_{max.}$ 215 and 277 nm (log ε 4.32 and 3.68); $\nu_{max.}$ 2 140 (N_3), 1 625, 1 540, 1 510, 1 460, 1 445, 1 380, and 780 cm^{-1}; δ 0.72, 0.86, 0.90, and 0.96 (methyl groups), and 8.66 (s, 1 H, 5′-H) (Found: C, 75.2; H, 9.95; N, 15.15%; M^+, 463.364 704. $C_{29}H_{45}N_5$ requires C, 75.10; H, 9.75; N, 15.11%; *M*, 463.367 478).

11-*Oxo*-5α-*spirost*-2-*eno*[2,3-g](*tetrazolo*[1,5-a]*pyrimidine* (17). This was recrystallised from ethanol to give a yellow solid (65%), m.p. 200—202 °C; $\lambda_{max.}$ 214 and 279 nm (log ε 4.32 and 3.70); $\nu_{max.}$ 2 140 (N_3), 1 700 (C=O), 1 630, 1 545, 1 510, 1 450, 1 390, 1 050, 980, 920, 890, and 780 cm^{-1}; δ 0.76 (s, 3 H, 18-Me), 1.24 (s, 3 H, 19-Me), and 8.68 (s, 1 H, 5′-H) (Found: 68.82; H, 7.79; N, 13.73%; M^+, 505.303 706. $C_{29}H_{39}N_5O_3$ requires C, 68.87; H, 7.78; N, 13.85%; *M*, 505.305 273).

17β-*Hydroxyandrost*-4-*eno*[3,2-f](*tetrazolo*[1,5-a]*pyrimidine*) (19a). This was recrystallised from ethanol to give yellow crystals (37%), m.p. 143—146 °C; $\lambda_{max.}$ 213, 243, and 311 nm (log ε 4.15, 4.11, and 4.06); $\nu_{max.}$ 3 600 (OH), 2 140 (N_3), 1 620, 1 500—1 515, 1 430, 1 415, 1 380, and 780 cm^{-1}; δ 0.80 (s, 3 H, 18-Me), 1.06 (s, 3 H, 19-Me), 3.68 (t, 1 H, 17-H), 6.48 (s, 1 H, 4-H), and 8.60 (s, 1 H, 7′-H) (Found: C, 68.75; H, 7.5; N, 19.1%; M^+, 361.188 867. $C_{21}H_{23}N_5O$ requires C, 68.99; H, 7.45; N, 19.17%; *M*, 361.190 250).

17β-*Acetoxyandrost*-4-*eno*[3,2-f](*tetrazolo*[1,5-a]*pyrimidine*) (21a) *and* 17β-*Acetoxy*-4-*oxo*-5ζ-*androst*-2-*eno*[2,3-g](*tetrazolo*-[1,5-a]*pyrimidine*) (22a).—A solution of 17β-hydroxyandrost-4-eno[3,2-*f*](tetrazolo[1,5-*a*]pyrimidine) (19a) (0.45 g, 1.23×10^{-3} mol) in pyridine (25 ml) containing a few drops of acetic anhydride was refluxed for 2 h. The excess of solvent was removed *in vacuo* and the residue was taken up in chloroform. The chloroform solution was washed with 5% hydrochloric acid solution, water, and finally with saturated sodium chloride solution. The chloroform solution was dried ($MgSO_4$), evaporated to dryness *in vacuo*, and the residue thus obtained was chromatographed over alumina. Elution with methylene chloride followed by recrystallisation of the eluate from methanol gave yellow crystals of 17β-*acetoxyandrost*-4-*eno*[3,2-f](*tetrazolo*[1,5-a]*pyrimidine*) (21a) (0.125 g, 25%), m.p. 217—219 °C; $\lambda_{max.}$ 213, 243, and 311 nm (log ε 4.18, 4.22, and 4.19); $\nu_{max.}$ 2 140 (N_3), 1 720 (C=O), 1 615, 1 515, 1 505, 1 430, 1 420, 1 375, 1 360, and 780 cm^{-1}, δ 0.85 (s, 3 H, 18-Me), 1.05 (s, 3 H, 19-Me), 2.05 (s, 3 H, 17-OCOMe), 4.60 (t, 1 H, 17-H), 6.45 (s, 1 H, 4-H), and 8.60 (s, 1 H, 7′-H) (Found: C, 67.5; H, 7.0; N, 16.8%; M^+, 407.230 336. $C_{23}H_{29}N_5O_2$ requires C, 67.78; H, 7.14; N, 17.20%; *M*, 407.232 112).

Further elution of the column with chloroform followed by recrystallisation of the eluate from ethanol gave a yellow solid of 17β-acetoxy-4-oxo-5ζ-androst-2-eno[2,3-*g*](tetrazolo-[1,5-*a*]pyrimidine) (22a) (0.185 g, 37%), m.p. 235—237 °C; $\lambda_{max.}$ 214, 249, and 287 nm (log ε 4.13, 3.98, and 3.81); $\nu_{max.}$ 2 140 (N_3), 1 720 (C=O, acetyl group), 1 685 (ring C=O), 1 625, 1 545, 1 510, 1 430, 1 415, 1 370, and 780 cm^{-1}; δ 0.85 (s, 6 H, 18- and 19-Me), 2.05 (s, 3 H, 17-OCOMe), 4.65 (t, 1 H, 17-H), and 8.65 (s, 1 H, 5′-H) (Found: C, 65.3; H, 6.95; N, 16.25%; M^+, 423.226 596. $C_{23}H_{29}N_5O_3$ requires C, 65.21; H, 6.91; N, 16.54%; *M*, 423.227 026).

6,7-*Dihydro*-5H-*cyclopenta*[f]*tetrazolo*[1,5-a]*pyrimidine* (24a).—This was recrystallised from ethanol to give white crystals (55%), m.p. 152—154 °C (lit.,[6] m.p. 152—153 °C); $\nu_{max.}$ 2 140 (N_3), 1 655, 1 635, 1 530, 1 500, 1 405, 1 345, and 775 cm^{-1}; δ 2.35 (m, 2 H, 6-H_2), 3.15 (m, 4 H, 5-H_2 and 7-H_2), and 8.70 (t, 1 H, 8-H).

3β-*Hydroxyandrost*-5-*eno*[17,16-f](*tetrazolo*[1,5-a]*pyrimidine*) (27).—Alumina chromatography (eluant chloroform) of the crude product followed by recrystallisation from ethanol gave white crystals of the title compound (54%), m.p. 198—200 °C; $\nu_{max.}$ 3 590 (OH), 2 140 (N_3), 1 645, 1 540, 1 500, 1 465, 1 455, 1 405, 1 375, and 790 cm^{-1}; δ 1.12 (s, 3 H, 18-Me), 1.15 (s, 3 H, 19-Me), 3.70 (m, 1 H, 3-H), 5.40 (t, 1 H, 6-H), and 8.70 (s, 1 H, 7′-H) (Found: C, 68.75; H, 7.5; N, 19.15%; M^+, 365.220 461. $C_{21}H_{27}N_5O$ requires C, 68.99; H, 7.45; N, 19.17%; *M*, 365.221 549).

3β-*Acetoxyandrost*-5-*eno*[17,16-f](*tetrazolo*[1,5-a]*pyrimidine*) (28).—The above product (27) (0.450 g, 1.23×10^{-3} mol) was acetylated using the method described before the preparation of the compound (21a) to give its 3β-acetate. Recrystallisation of the crude product from ethanol gave 3β-acetoxyandrost-5-eno[17,16-*f*](tetrazolo[1,5-*a*]pyrimidine) (28) (0.27 g, 54%), m.p. 241—244 °C; $\nu_{max.}$ 1 725 (C=O), 2 140 (N_3), 1 645, 1 500, 1 455, 1 435, 1 410, 1 375, and 790 cm^{-1}; δ 1.12 (s, 6 H, 18- and 19-Me), 2.03 (s, 3 H, 3-OCOMe), 4.60 (m, 1 H, 3-H), 5.40 (t, 1 H, 6-H), and 8.70 (s, 1 H, 7′-H) (Found: C, 67.45; H, 7.0; N, 16.95%; $M^+ - MeCO_2H$, 347.209 509. $C_{23}H_{29}N_5O_2$ requires C, 67.78; H, 7.14; N, 17.20%; $M - MeCO_2H$, 347.210 985).

3-*Methoxyestra*-1,3,5(10)-*trieno*[17,16-f](*tetrazolo*[1,5-a]*pyrimidine*) (30).—This was recrystallised from ethanol to give white crystals (92%), m.p. 235—237 °C; δ ([$^2H_6$]DMSO), 1.08 (s, 3 H, 18-Me), 3.70 (s, 3 H, 3-OMe), 6.60—7.22 (m, 3 H, 1-H, 2-H, and 4-H), and 9.26 (s, 1 H, 7-H) (Found: C, 69.0; H, 8.15; N, 18.5%; M^+, 361.188 867. $C_{21}H_{23}N_5O$ requires C, 69.24; H, 8.19; N, 18.36%; *M*, 361.190 250).

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