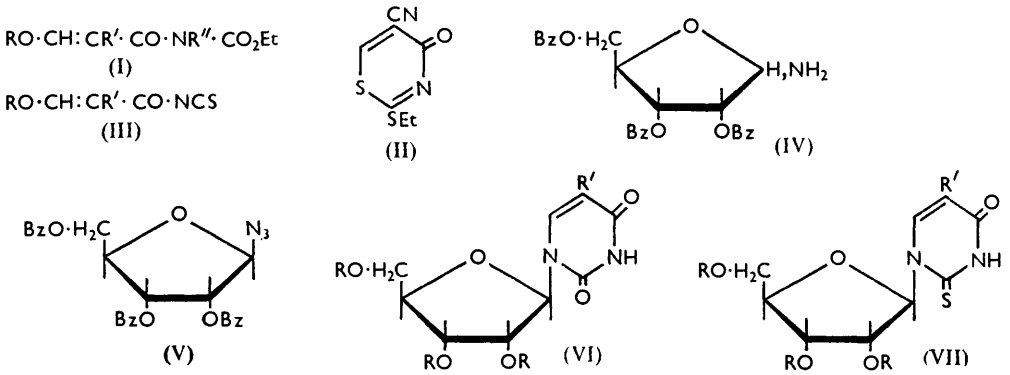
463. *Purines, Pyrimidines, and Glyoxalines. Part IX.* Syntheses of Uridine, 2-Thiouridine, and Some Related Compounds.*

By G. Shaw, R. N. Warrener, and (in part) (Miss) M. H. Maguire and R. K. Ralph.

Uridine, 5-cyanouridine, 2-thiouridine, 5-methyl-2-thiouridine, and 5-cyano-2-thiouridine have been prepared by reaction of acrylamides (I), acyl *iso*thiocyanates (III), or the cyanothiazine (II) with 2 : 3 : 5-tri-*O*-benzoyl-D-ribosylamine (IV) and debenzoylation of the products. The apparent exclusive formation of β-glycosides in these reactions is discussed.

In Part II [1] of this series we described an unambiguous synthesis of 1-substituted pyrimidine nucleosides, by reaction of several D-glycosylamines (1-amino-1-deoxy-sugars or tautomers thereof) with the acrylamides (I; R = Et, R′ = CN, R″ = H or Me). Periodate titrations of these nucleosides showed that they had the pyranose configuration, and their specific rotations suggested the β-glycosidic configuration.

In other Parts of this series we described the preparation of some precursors of uracils and 2-thiouracils in which a 1-substituent is introduced by way of a primary amino-compound. These precursors include the urethane * (I; R = Et, R′ = R″ = H), the cyanothiazine [2] (II), and the acyl *iso*thiocyanates [3] (III; R = Et, R′ = H; and R = R′ = Me) which should be suitable for the preparation of nucleosides by similar reactions with glycosylamines.



Application of our methods to the synthesis of pyrimidine nucleosides related to the ribofuranosides of natural origin required β-D-ribofuranosylamine or a suitable derivative thereof. Such a compound, 2 : 3 : 5-tri-*O*-benzoyl-D-ribosylamine (IV), has recently been prepared by catalytic hydrogenation of 2 : 3 : 5-tri-*O*-benzoyl-β-D-ribosyl azide (V) obtained from the ribosyl halide and sodium azide in methyl cyanide.[4] The method is an extension of one used by Bertho for the preparation of 2 : 3 : 4 : 6-tetra-*O*-acetylglucosyl azide and D-glucosylamine.[5]

From its method of preparation, the ribosylamine (IV) would formally be expected to have the β-configuration. However, the isolation of α- and β-glycyl derivatives of the amino-sugar [4] suggests that mutarotation occurs readily and that the ribosylamine is perhaps best regarded as an αβ-mixture.

Reaction of the ribosylamine (IV) with the acrylamide (I; R = Et, R′ = R″ = H) in

* Part VIII, *J.*, 1958, 157.

[1] Ralph and Shaw, *J.*, 1956, 1877.
[2] Atkinson, Shaw, Schaffner, and Warrener, *J.*, 1956, 3847.
[3] Shaw and Warrener, *J.*, 1958, 153.
[4] Baddiley, Buchanan, Hodges, and Prescott, *Proc. Chem. Soc.*, 1957, 148; *J.*, 1957, 4769.
[5] Bertho, *Ber.*, 1930, **63**, 836.

ethyl acetate, in the presence of triethylamine, and debenzoylation of the product with methanolic sodium methoxide gave uridine (VI; R = R′ = H), the identity of which was confirmed by comparison with an authentic specimen. Only one other synthesis of uridine has been recorded,[6] by deamination of cytidine which was prepared by the Hilbert–Johnson method [7] from acetobromoribofuranose and 2 : 6-diethoxypyrimidine and then reaction of the product with ammonia.

The similar reaction of the ribosylamine with the acrylamide (I; R = Et, R′ = CN, R″ = H) and the cyanothiazine (II) gave crystalline tri-*O*-benzoates (VI; R = Bz, R′ = CN) and (VII; R = Bz, R′ = CN) respectively. Debenzoylation as before then afforded 5-cyanouridine (VI; R = H, R′ = CN) and 5-cyano-2-thiouridine (VII; R = H, R′ = CN).

The acyl *iso*thiocyanate (III; R = R′ = Me) also readily afforded a crystalline tri-*O*-benzoate (VII; R = Bz, R′ = Me) but debenzoylation of this as above or with alcoholic ammonia gave non-crystalline material. Ultraviolet absorption spectra of the crude material and of material purified by elution from paper chromatograms and cellulose powder columns, were unlike those expected of a 1-substituted 2-thiouracil, but very similar to those of 1-substituted 2-alkylthio- or 2-alkoxy-pyrimidines, which show maximum absorption at about 245 mμ, unchanged in acid or alkaline solution.[8] These results are difficult to explain for, although thiouracils are known to undergo nucleophilic replacement reactions, these are confined to the 4-thio-derivatives. Thus, 2 : 4-dithiouracil when heated with ammonia or amines gives 2-thiocytosine and derivatives, replacement of sulphur occurring only in the 4-position.[9] In addition, in a model experiment, 1-methyl-2-thiothymine was recovered in good yield after treatment with methanolic sodium methoxide under conditions even more vigorous than those used for the tri-*O*-benzoate (VII; R = Bz, R′ = Me). The latter compound was eventually successfully converted into 5-methyl-2-thiouridine (VII; R = H, R′ = Me) by sodium hydroxide in aqueous, peroxide-free dioxan.

Reaction of the acyl *iso*thiocyanate (III; R = Et, R′ = H) with the ribosylamine (IV) and hydrolysis of the product with sodium hydroxide in aqueous dioxan similarly gave 2-thiouridine (VII; R = R′ = H).[10] Sodium methoxide gave results analogous to those with the 5-methyl derivative.

Confirmation of the structure of the 2-thiouridine was obtained by heating it for several hours with aqueous chloroacetic acid. Paper chromatography of the solution in butanol saturated with 3% aqueous boric acid gave spots corresponding to unchanged 2-thiouridine (R_F 0·3) and uridine (R_F 0·15). The latter material was eluted with buffer solutions, whose ultraviolet absorption was then identical with that of uridine at the same pH values.

Strominger and Friedkin [11] reported enzymic formation of a 2-thiouracil riboside on incubating together 2-thiouracil and ribose 1-phosphate with thymidine phosphorylase. This riboside was not obtained crystalline but was purified by elution from paper chromatograms with butanol saturated with 3% aqueous boric acid. Its identity as a 1-ribosyl-2-thiouracil followed from its stability to acid, its ultraviolet absorption in acid and alkaline solutions (where differences occur, characteristic of 1-substituted 2-thiouracils), and its enzymic arsenolysis to 2-thiouracil and ribose. By analogy with similar enzymic Kalckar syntheses,[12] it seemed likely that the substance was 2-thiouridine.

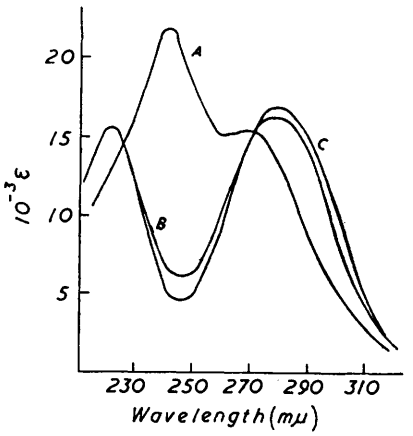
Our material appears to be very similar to that prepared by Strominger and Friedkin. The ultraviolet spectra (see Fig. 1) are identical with those reported for acid, neutral,

[6] Howard, Lythgoe, and Todd, *J.*, 1947, 1052.
[7] Hilbert and Johnson, *J. Amer. Chem. Soc.*, 1930, **52**, 2001, 4489.
[8] Shugar and Fox, *Bull. Soc. chim. belges*, 1952, **61**, 293.
[9] Hitchings, Elion, Falco, and Russell, *J. Biol. Chem.*, 1949, **177**, 357.
[10] Cf. Shaw and Warrener, *Proc. Chem. Soc.*, 1957, 351.
[11] Strominger and Friedkin, *J. Biol. Chem.*, 1954, **208**, 663.
[12] Kalckar, *Biochim. Biophys. Acta*, 1953, **12**, 250.

and alkaline solution except at wavelengths in the 220 mμ region where in our pure material we did not observe the enhanced absorption recorded for the enzymically prepared material, although such absorption was present in our less pure material. The R_F of our material in butanol saturated with 3% aqueous boric acid was about 0·3 which differs slightly from that recorded by Strominger and Friedkin for their material (0·25), but we regard this as of little significance since we have found that the solvent system used here does not readily give repeatable R_F values, although it is excellent for the separation of closely related nucleosides. A substance corresponding to 2-thiouridine has also been identified among the hydrolysates of [^{35}S]-2-thiouracil-treated tobacco mosaic virus,[13] being located as a radioactive spot on paper chromatograms, with an R_F value similar to that of uridine. Our material also on paper chromatography in solvent systems other than butanol–boric acid behaves similarly to uridine.

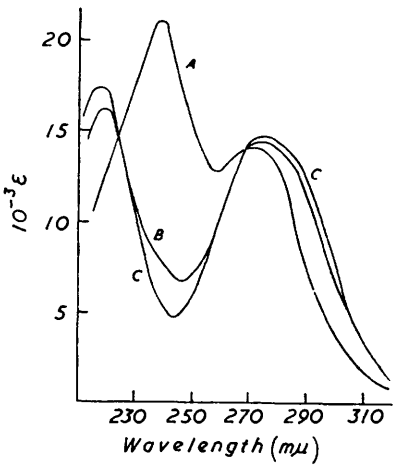
It seems most likely that all the pyrimidine nucleosides mentioned above, in addition to those described in Part II,[1] have the β-configuration at the glycosidic centre and this is

FIG. 1. *Absorption spectra of 2-thiouridine.*



A, 0·2M-K_2HPO_4, pH 9; *B*, M/15-Na_2HPO_4–M/15-KH_2PO_4 (4 : 1), pH 7·4; *C*, 0·01N-HCl.

FIG. 2. *Absorption spectra of 5-methyl-2-thiouridine.*



A, *B*, *C* as in Fig. 1.

confirmed by specific rotation values, and by analogy with the cases (uridine and 2-thiouridine) where additional proof is available. No isomeric α-glycosides have been detected among the products although their presence cannot be excluded.

In our experiments, pyrimidine formation in all cases must proceed through initial formation of linear intermediates of the type ribose–NH·CS·NH·CO·CR:CH·OR′ and ribose–NH·CH:CR′·CO·NH·CO_2Et and compounds of this type have been isolated when simple primary amines have been used (Part VIII and ref. 3).

An examination of molecular models suggests that cyclisation of the β-forms of these linear compounds should occur more readily than with the corresponding α-anomers which may accompany them. In the latter forms, the NH group is sterically hindered by the 2′-*O*-benzoyl group, and hindrance to cyclisation could be augmented by a tendency to oxazoline formation involving the reaction, $^-$NH + $^-$COPh ⟶ –N·CPh(OH)·.

Our results parallel the apparent exclusive formation in nature of the β-forms of pyrimidine and purine nucleosides, and it seems possible that the above remarks may provide a common explanation of these observations. Indeed one suggested route to pyrimidine nucleosides involves reactions and intermediates very similar to those described

[13] Mandel, Markham, and Matthews, *Biochim. Biophys. Acta*, 1957, **24**, 205.

in this paper.[14] In addition it has recently been shown that a ribofuranosylamine, namely, 5-phosphoribosylamine, is a precursor of purine nucleotides in biochemical systems,[15] and it seems likely that the same compound is concerned with biosynthesis of pyrimidine nucleotides.

Experimental

Dioxan was freed from peroxides by distillation from stannous chloride, and used immediately. Rotations were measured in water.

Uridine.—2 : 3 : 5-Tri-*O*-benzoyl-β-D-ribofuranosyl azide (1 g.) was reduced in dry " AnalaR " ethyl acetate (15 ml.) (ethyl acetate distilled from Raney nickel is also suitable), over a platinic oxide catalyst (0·1 g.) for 2 hr. Nitrogen produced during the reaction was removed by flushing the apparatus twice with hydrogen at intervals of about 45 min. To the dried (Na_2SO_4) filtered solution were added β-ethoxy-*N*-ethoxycarbonylacrylamide (0·5 g.) and triethylamine (1 ml.), and the mixture was boiled under reflux for 1 hr. The cooled solution was washed with dilute hydrochloric acid and water, dried, and evaporated to a gum. This was dissolved in methanol (10 ml.) containing a little sodium methoxide and set aside for 24 hr. The solvent was removed *in vacuo* and the residue dissolved in water and extracted with ether. The aqueous solution was treated with basic lead acetate solution, and the precipitated lead salt centrifuged off, washed with a little water, and methanol, then suspended in methanol and decomposed with hydrogen sulphide. Lead sulphide was removed, and the solution evaporated to a crystalline residue. Uridine (0·2 g.) separated from ethanol as needles, m. p. and mixed m. p. 165°, $[\alpha]_D$ +8° (*c* 1·5) (Found: C, 44·1; H, 5·1; N, 11·25. Calc. for $C_9H_{12}O_6N_2$: C, 44·25; H, 4·9; N, 11·45%).

2′ : 3′ : 5′-*Tri*-O-*benzoyl*-5-*cyanouridine.*—The ribosyl azide (1 g.) in ethyl acetate (100 ml.) was reduced as before. The filtered solution was treated with α-cyano-β-ethoxy-*N*-ethoxycarbonylacrylamide [16] (0·5 g.) and triethylamine (1 ml.), then boiled under reflux for 1 hr. The cooled solution was washed with dilute hydrochloric acid and water, dried, and evaporated to a gum. This was dissolved in warm ethanol (10 ml.) and set aside: an amorphous solid separated. This was removed and the filtrate evaporated to a small volume and kept at 0° overnight, a crystalline precipitate separating. 2′ : 3′ : 5′-*Tri*-O-*benzoyl*-5-*cyanouridine hemihydrate* (0·3 g.) separated from ethanol as needles, m. p. 190° (Found: C, 63·05; H, 4·15; N, 6·95. $C_{31}H_{23}O_9N_3,\frac{1}{2}H_2O$ requires C, 63·05; H, 4·1; N, 7·1%), $\lambda_{max.}$ 230 mμ (ε 38,400), 276 mμ (ε 13,200), λ_{min} 253 mμ (ε 5900) in EtOH.

5-*Cyanouridine.*—The preceding reaction was repeated and the product dissolved in methanol (10 ml.) containing sodium methoxide and set aside for 24 hr. The whole was worked up as for uridine, to give 5-*cyanouridine* (0·25 g.) as needles (from ethanol), m. p. 185°, $[\alpha]_D^{20}$ −6° (*c* 2·0) (Found: C, 44·5; H, 4·1; N, 15·75. $C_{10}H_{11}O_6N_3$ requires C, 44·6; H, 4·1; N, 15·6%), $\lambda_{max.}$ 276 mμ (ε 14,800) and 216 mμ (ε 13,000), $\lambda_{min.}$ 240 mμ (ε 2450) in H_2O. In 24 hr. at 18° the substance had consumed 1·05 mols. of 0·09N-sodium metaperiodate; no acid was formed in the reaction.

2′ : 3′ : 5′-*Tri*-O-*benzoyl*-5-*cyano*-2-*thiouridine.*—The ribosyl azide (3 g.) in ethyl acetate (250 ml.) was reduced over platinic oxide (0·3 g.) as before. The filtered solution was treated with 5-cyano-4-oxo-2-thio-1 : 3-thiazine (1·3 g.) and triethylamine (1 ml.) and boiled under reflux for 1 hr. The acid- and water-washed solution was dried and evaporated *in vacuo* to a gum. This was dissolved in warm benzene (15 ml.), and the solution set aside. 2′ : 3′ : 5′-*Tri*-O-*benzoyl*-5-*cyano*-2-*thiouridine* (1 g.) crystallised; it recrystallised from benzene as needles, m. p. 169° which retained benzene (Found, in material dried at 70°/0·1 mm.: C, 64·45; H, 4·0; N, 7·1. $C_{31}H_{23}O_8N_3S,\frac{1}{2}C_6H_6$ requires C, 64·15; H, 4·1; N, 6·6%. Found, in material dried at 120°/0·01 mm.: C, 63·3; H, 4·0. $C_{31}H_{23}O_8N_3S,\frac{1}{4}C_6H_6$ requires C, 63·2; H, 4·0%).

5-*Cyano*-2-*thiouridine.*—(*a*) The tribenzoate (0·5 g.) in methanol (20 ml.) containing a little sodium methoxide was kept overnight, then neutralised with acetic acid and evaporated *in vacuo* to dryness. The residue was dissolved in water and worked up as for uridine. 5-*Cyano*-2-*thiouridine* (0·12 g.) crystallised from ethanol as prisms, m. p. 185—186°, $[\alpha]_D^{18}$ +10° (*c* 1·0) (Found: C, 41·9; H, 4·1; N, 14·5. $C_{10}H_{11}O_5N_3S$ requires C, 42·1; H, 3·9; N, 14·75%), $\lambda_{max.}$ 300 mμ (ε 13,200), 271 mμ (ε 12,300), 223 mμ (ε 13,600) in H_2O; $\lambda_{max.}$ 291 mμ (ε 19,500), 267 mμ

[14] Mitchell and Houlahan, *Fed. Proc.*, 1947, **6**, 506.
[15] Goldthwaite, Greenberg, and Peabody, *Biochim. Biophys. Acta*, 1955, **18**, 148; Goldthwaite, *J. Biol. Chem.*, 1956, **222**, 1051.
[16] Shaw, *J.*, 1955, 1834.

(ε 14,500), 235 mμ (ε 18,400) in 0·2M-dipotassium hydrogen phosphate. (*b*) The tribenzoate (1 g.) in methanol (25 ml.) was treated with saturated methanolic ammonia (10 ml.), then set aside for 2 days. The solution was evaporated *in vacuo* and the residue extracted with ether. The remaining solid was dissolved in a little ethanol and seeded, to give after a few hours, 5-cyano-2-thiouridine (0·27 g.), m. p. and mixed m. p. 186°.

5-Cyano-2′ : 3′-isopropylidene-2-thiouridine.—The foregoing tribenzoate (0·7 g.) was debenzoylated as described in (*b*) above. The crude 5-cyano-2-thiouridine was shaken occasionally during 2 days with acetone (10 ml.), anhydrous copper sulphate (1 g.), and sulphuric acid (0·06 ml.). The mixture was filtered and the filtrate neutralised with solid sodium hydrogen carbonate. The solution was filtered and the filtrate evaporated to a solid residue. *5-Cyano-2′ : 3′-isopropylidene-2-thiouridine* (0·12 g.) separated from acetone–light petroleum (b. p. 40—60°) as needles, m. p. 189° (Found: C, 48·7; H, 4·65; N, 12·5. $C_{13}H_{15}O_5N_3S$ requires C, 48·0; H, 4·6; N, 12·9%).

2′ : 3′ : 5′-Tri-O-benzoyl-5-methyl-2-thiouridine.—The ribosyl azide (3 g.) in ethyl acetate (300 ml.) was reduced over platinic oxide (0·3 g.), and the filtered solution treated with β-methoxy-α-methylacryloyl *iso*thiocyanate (0·9 g.) and triethylamine (3 ml.). The solution was boiled under reflux for 1½ hr., cooled, and washed with N-hydrochloric acid (3 × 30 ml.) and water (5 × 30 ml.), dried, and evaporated *in vacuo* to a gum. When this was stirred with dry methanol (50 ml.) it rapidly crystallised. *2′ : 3′ : 5′-Tri-O-benzoyl-5-methyl-2-thiouridine* (1·61 g.) recrystallised from an excess of methanol as needles, m. p. 156—157°, which retained methanol (Found: C, 63·1; H, 5·15; N, 4·5. $C_{31}H_{26}O_8N_2S,\frac{1}{2}CH_3{\cdot}OH$ requires C, 62·8; H, 4·7; N, 4·65%), $\lambda_{max.}$ at 230 mμ (ε 40,900) and 262 mμ (ε 22,400), $\lambda_{infl.}$ 278 mμ (ε 20,400), $\lambda_{min.}$ 250 mμ (ε 17,900) in EtOH.

A solution of the tribenzoate (1 g.) in dry methanol (110 ml.) containing sodium methoxide (1 ml. of 1·9% solution in methanol) was boiled under reflux for 10 min., then set aside for 24 hr. The clear yellow solution was neutralised with Zeo-Karb 225 and evaporated to dryness *in vacuo*. The residue was treated with water which was then removed (accompanied by methyl benzoate) *in vacuo*. The residue was dissolved in water (20 ml.) and extracted with chloroform (3 × 7 ml.) and ether (10 ml.). Paper chromatography (ascending) of the aqueous solution in butanol saturated with water gave three absorbing spots with R_F 0·1, 0·2 (strong), and 0·5. The solution was evaporated and the residue chromatographed on a cellulose powder column, butanol saturated with water being used as solvent system. A main fraction (R_F 0·22) was isolated from the column as a brittle gum (Found: C, 35·4; H, 5·8; N, 11·1%), $\lambda_{max.}$ 242 mμ unchanged in acid or alkali. Similar results were obtained when the conditions were varied and when methanolic ammonia was used.

1-Methyl-2-thiothymine [3] (0·1 g.) in methanol (20 ml.) containing sodium (0·023 g.) was refluxed for 6 hr., then kept at room temperature for 3 days. The solution was neutralised with Zeo-Karb 225, warmed to dissolve a precipitate, and evaporated. Crystallisation of the residue from water gave 1-methyl-2-thiothymine (0·06 g.), m. p. and mixed m. p. 230°.

5-Methyl-2-thiouridine.—The foregoing tribenzoate (2·7 g.) in dioxan (30 ml.) was treated with 2N-sodium hydroxide (23 ml.) and water (6 ml.) to give a homogeneous solution, which was set aside for 24 hr., then neutralised with 2N-hydrochloric acid (23 ml.); an unpleasant mercaptan-like odour was apparent after addition of the acid. The solvent was removed *in vacuo* and the residue treated with water (50 ml.), and the precipitated benzoic acid removed with ether (3 × 30 ml.). The aqueous phase was evaporated to about 15 ml. and continuously extracted with ethyl acetate for 5 hr. The solution was cooled and set aside, giving a crystalline precipitate; *5-methyl-2-thiouridine* (0·45 g.) recrystallised from dry ethanol as needles, m. p. 217°, $[\alpha]_D^{28}$ +31° (*c* 1·23) (Found: C, 43·75; H, 4·9; N, 10·4. $C_{10}H_{14}O_5N_2S$ requires C, 43·8; H, 5·15; N, 10·2%). A further quantity of the nucleoside (0·15 g.) was recovered by evaporation of the ethyl acetate solution to dryness and crystallisation of the residue from ethanol. In butanol saturated with 3% aqueous boric acid the nucleoside had R_F 0·5, and in butanol–acetic acid–water (5 : 2 : 3) R_F 0·56 (ascending paper chromatography).

2-Thiouridine.—The ribosyl azide (3 g.) in ethyl acetate (300 ml.) was reduced over platinic oxide (0·3 g.), and the dried filtered solution treated with β-ethoxyacryloyl *iso*thiocyanate (0·9 g.) and triethylamine (3 ml.), then boiled under reflux for 2 hr. The acid- and water-washed solution was dried and evaporated *in vacuo* to a gum. This was dissolved in dioxan (40 ml.), and 2N-sodium hydroxide (15·4 ml.) and water (8·5 ml.) were added to give a homogeneous solution, which was set aside for 24 hr., then neutralised with 2N-hydrochloric acid

(15·4 ml.). The solution was evaporated to dryness *in vacuo*, then treated with water (50 ml.). Precipitated benzoic acid was removed by extraction with ether (3 × 30 ml.). The aqueous solution was then evaporated *in vacuo* to about 15 ml. and continuously extracted with ethyl acetate for 16 hr. The extract was evaporated to dryness *in vacuo* and the residual solid crystallised from aqueous ethanol, to give 2-*thiouridine* (0·3 g.) as needles, m. p. 214°, $[\alpha]_D^{20}$ +39° (*c* 1·2) (Found: C, 41·4; H, 4·75; N, 10·6. $C_9H_{12}O_5N_2S$ requires C, 41·55; H, 4·65; N, 10·75%). In butanol saturated with 3% aqueous boric acid the nucleoside had R_F 0·3 (the value varied with the length of run and possibly with temperature, values being recorded to about 0·35), and in butanol–acetic acid–water (5 : 2 : 3) R_F 0·52. Uridine had R_F 0·47 in the latter solvent system and R_F about 0·15 in the former with variations to R_F 0·18 similar to those obtained with the thio-derivative.

Debenzoylation of the above reaction mixture with methanolic sodium methoxide or ammonia gave results similar to those obtained with the 5-methyl derivative.

Conversion of 2-Thiouridine into Uridine.—A solution of 2-thiouridine (5 mg.) in water (0·23 ml.) was heated on a water-bath, and chloroacetic acid (0·1 g.) was added in small portions at 8 hourly intervals. Ascending paper chromatography of the solution showed the presence of two absorbing spots (in butanol saturated with 3% aqueous boric acid), which corresponded to 2-thiouridine and uridine which were run at the same time. The reaction solution was run on paper as a strip, and the band corresponding to uridine cut out and divided into 2 parts, one of which was extracted with 0·2M-dipotassium hydrogen phosphate (pH 9·2) and the other with M/15-disodium hydrogen phosphate–M/15-potassium dihydrogen phosphate (4 : 1) (pH 7·4). Ultraviolet absorption spectra of these solutions were identical with those given by uridine in the same solvents with $\lambda_{max.}$ 262 mμ in each case and $\lambda_{min.}$ showing a characteristic change from 232 mμ (pH 7·4) to 239 mμ (pH 9·2). Calculations from known extinction coefficients for uridine indicated that the yield of uridine in the above reaction was approximately 15%. The synthetic uridine similarly had the same behaviour as the natural material when chromatographed on paper in butanol–acetic acid–water (5 : 2 : 3).

We thank the N.S.W. State Cancer Council for a research grant and Dr. E. Challen for microanalyses. Part of this work was carried out at the University Chemical Laboratories, Cambridge, by one of us (G. S.) during the tenure of a Nuffield Dominion travelling fellowship.

N.S.W. University of Technology,
Sydney, N.S.W., Australia.

[*Received, December 10th*, 1957.]