Cyclophilic Reactions of Allene-1,3-dicarboxylic Ester. Part 7.[1] Synthesis of Bicyclic and Tricyclic Heterocyclic Compounds Involving Nitrogen, Sulphur, and Carbon as Nucleophiles

Gurinder J. S. Doad, Dorcas I. Okor, and Feodor Scheinmann *,†
The Ramage Laboratories, Department of Chemistry and Applied Chemistry, University of Salford, Salford M5 4WT, U.K.
Paul A. Bates and Michael B. Hursthouse
Department of Chemistry, Queen Mary College, University of London, London E1 4NS, U.K.

Dimethyl allene-1,3-dicarboxylate (**1**) is an excellent substrate for heterocyclic syntheses giving products with ester side-chains capable of further elaboration.

The allene (**1**) has been converted into the condensed pyridones (**8**)—(**13**) by reactions with 2-aminoazoles and azines and also into the pyridones (**15**) and (**17**) using benzamidine (**14**) and guanidine hydrochloride (**16**). Reactions with thiols lead to thiol-enol ethers (**19**), (**20**), (**24**), (**25**), and (**29**)—(**32**). The thiazopyrone (**22**) and thiazinone (**27**) were formed from 2-thiohydantoin (**21**) and 4-methyl thiosemicarbazide (**26**), respectively. The thiochromone (**33**) was obtained by cyclising the enol ethers (**29**)—(**32**). Thienopyridones (**37**) and (**40**) were formed from 2-aminothiophene-3-carboxylates (**35**) and (**38**) with the isolation of their respective enamine intermediates (**36**) and (**39**). The *X*-ray crystal structures of the pyridones (**9**) and (**11**) provide evidence for the mode of cyclisation. The 6-aminouracils (**41**) and (**45**) each react as an enamine in their mode of addition to (**1**) to give 7-oxopyrido[2,3-*d*]pyrimidines (**44**) and (**46**).

We have previously shown that allene-1,3-dicarboxylates are excellent substrates for heterocyclic syntheses. Thus five-membered heterocyclic compounds are formed by 1,3-dipolar addition reaction while six- and seven-membered heterocycles are synthesized by nucleophilic addition of amines, phenols, and mercapto groups to the central carbon atom of the allene-1,3-dicarboxylate system followed by cyclisation.[2]

We have now extended these studies to the synthesis of bicyclic and tricyclic heterocyclic compounds involving nitrogen and sulphur as nucleophiles in Michael additions followed by cyclisation of the adduct. Pyrimidine syntheses were readily achieved by reaction of dimethyl allene-1,3-dicarboxylate (**1**) with 2-amino nitrogen heterocycles such as 2-aminothiadiazole (**2**), 2-aminothioimidazole (**3**), 2-aminopyrimidine (**4**), 2-aminopyridine (**5**), 2-aminobenzimidazole (**6**), and 2-aminobenzothiazole (**7**). Heterocyclic formation occurred in all cases without the isolation of the intermediate to give methyl 7-oxo-7*H*-1,3,4-thiadiazolo[3,2-*a*]pyrimidin-5-yl acetate (**8**) (51%), methyl 7-oxo-7*H*-1,4-thiazolo[3,2-*a*]pyrimidin-5-yl acetate (**9**) (67%), methyl 2-oxo-2*H*-pyrimido[1,2-*a*]pyrimidin-4-yl acetate (**10**) (58%), methyl 2-oxo-2*H*-pyrido[1,2-*a*]pyrimidin-4-yl acetate (**11**) (73%), methyl 2,10-dihydro-2-oxopyrimido[1,2-*a*]-benzimidazol-4-yl acetate (**12**) (76%), and methyl 2-oxo-2*H*-pyrimido[2,1-*b*]benzothiazol-4-yl acetate (**13**) (63%) (Scheme 1). In each case one can assume that the Michael addition occurs at the heterocyclic nitrogen and this is then followed by lactam formation involving the exocyclic amine function. This is supported by similar reactions that occur with acetylene-dicarboxylic esters and/or ethyl propiolate[3-13] and *X*-ray crystallographic analysis of products (**9**) (Figure 1) and (**11**) (Figure 2). The generality of this reaction was also illustrated by the formation of pyrimidones (**15**) (42%) and (**17**) (38%) from reaction with benzamidine (**14**) and guanidine hydrochloride (**16**).

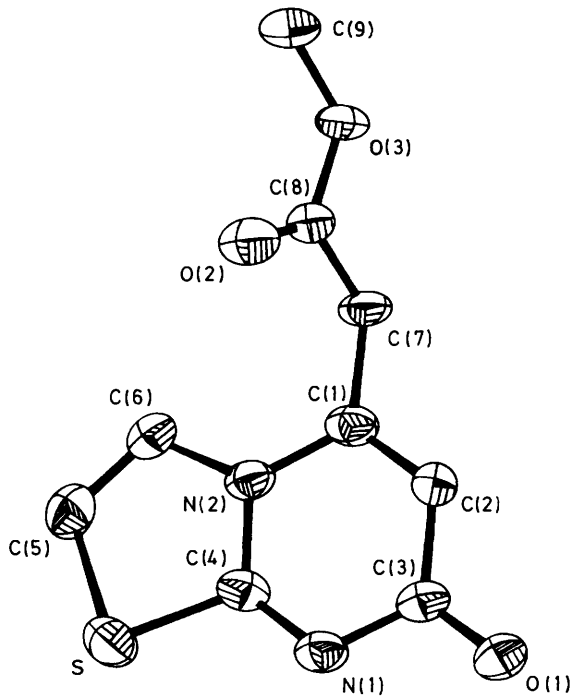
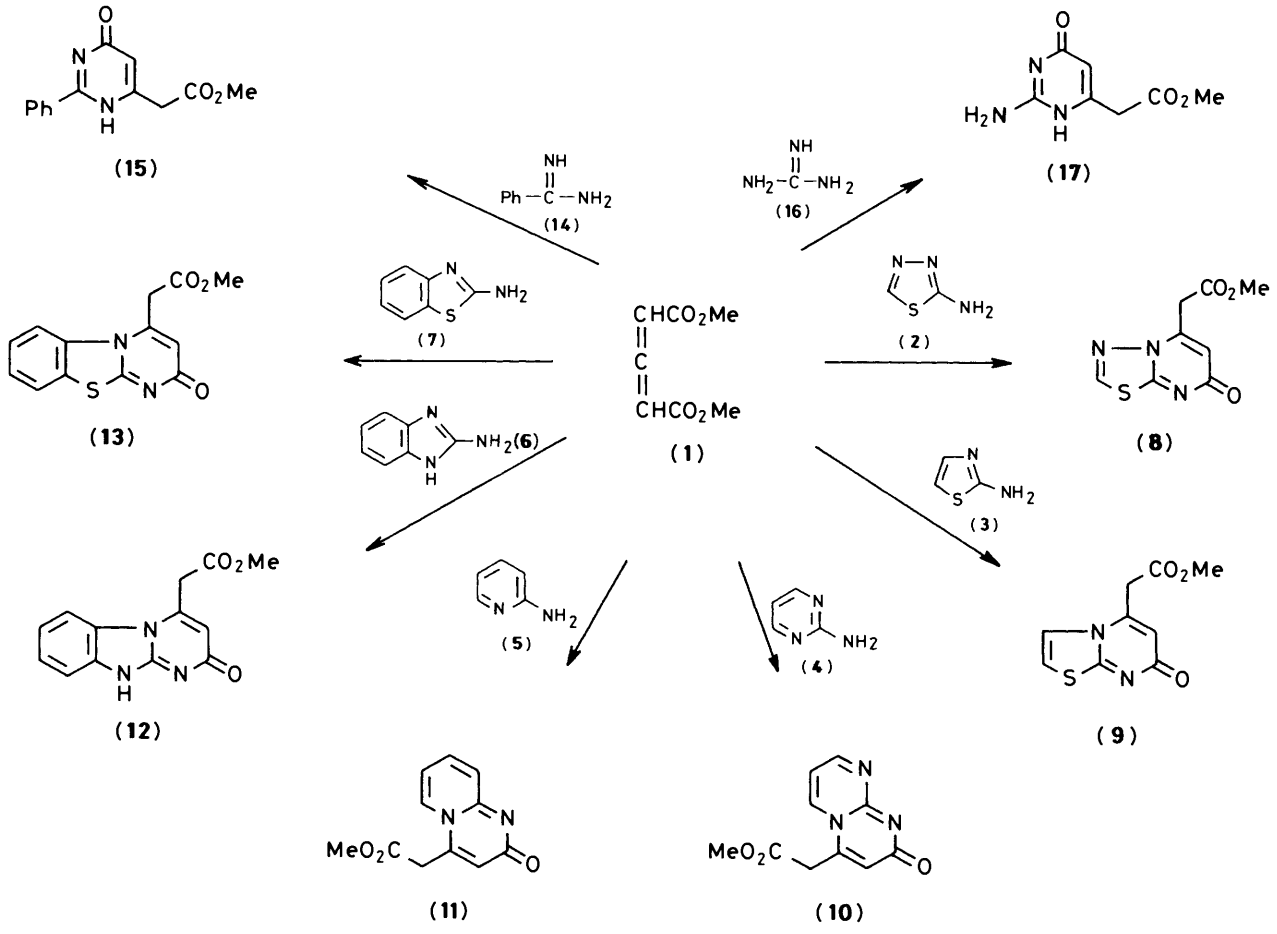


Figure 1. The molecular structure of compound (**9**). Hydrogen atoms have been omitted for clarity

We have previously shown that in reaction with dimethyl allene-1,3-dicarboxylate (**1**) sulphur is more nucleophilic than nitrogen.[14] This is further illustrated by reaction of 2-thiouracil (**18**), 2-thiohydantoin (**21**), 2-mercapto-1,3-benzothiazole (**23**), and 4-methylthiosemicarbazide (**26**). Both 2-thiouracil (**18**) and 2-mercapto-1,3-benzothiazole (**23**) underwent Michael addition with the allene (**1**), but the resulting intermediates failed to cyclise, whereas 2-thiohydantoin (**21**) and 4-methyl-

† *Present address:* Salford Ultrafine Chemicals and Research Ltd., Enterprise House, Manchester Science Park, Lloyd St., North, Manchester M15 4EN



Scheme 1.

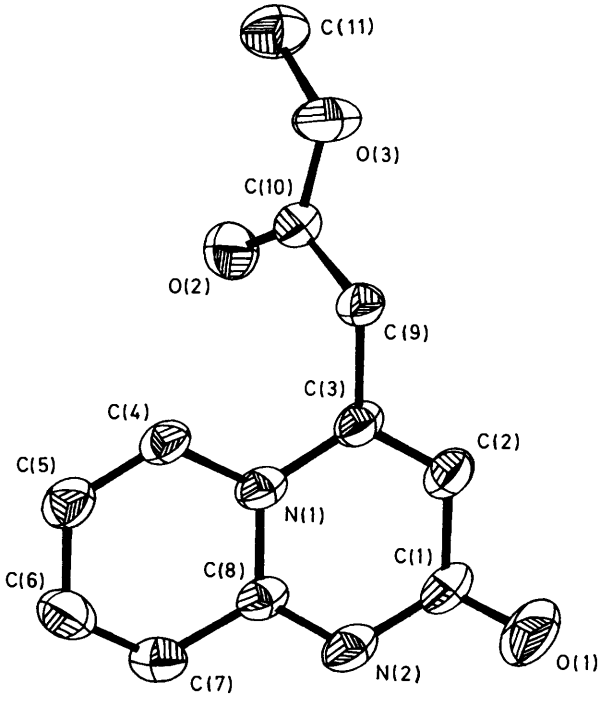
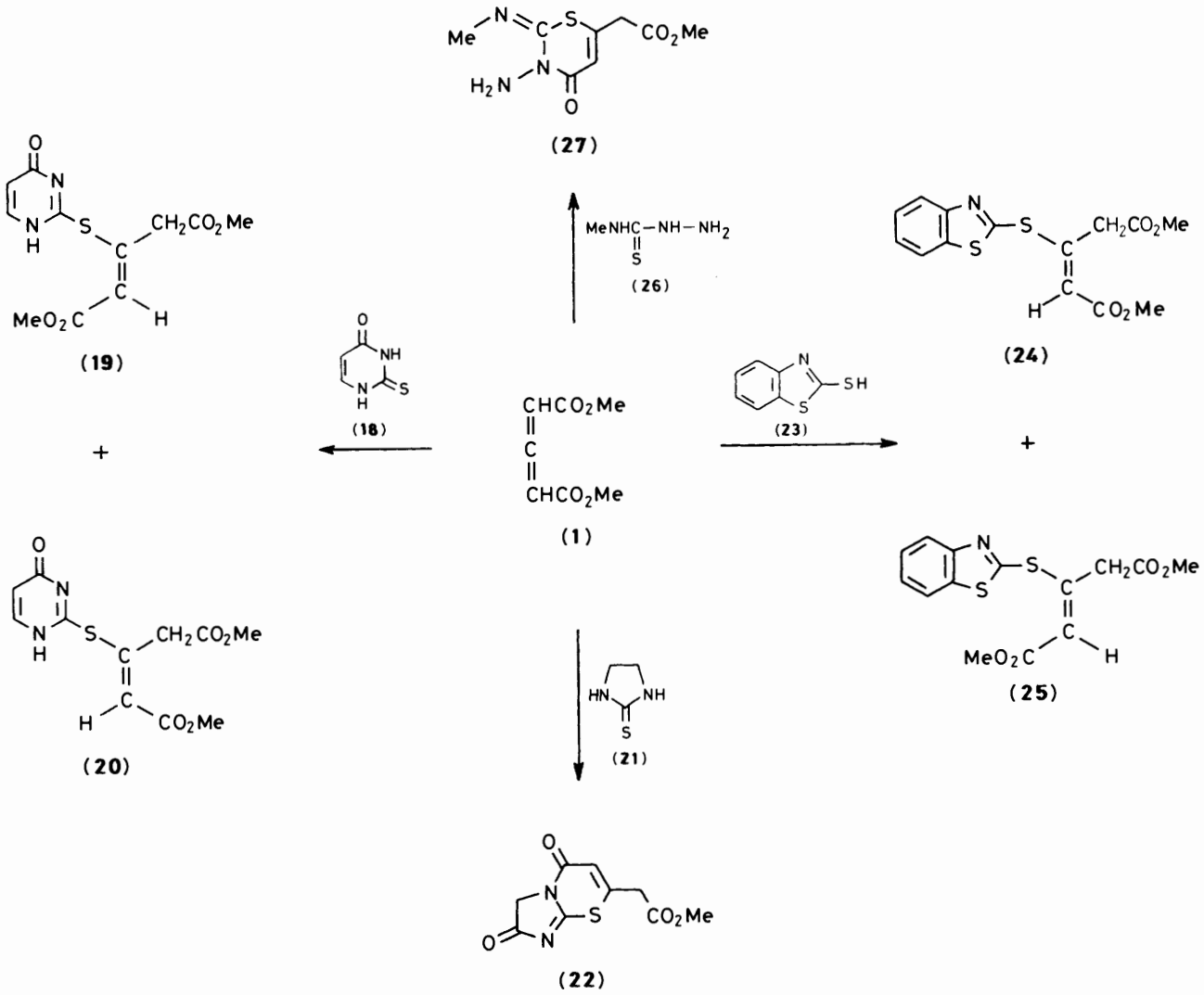


Figure 2. The molecular structure of compound (**11**). Hydrogen atoms have been omitted for clarity

thiosemicarbazide (**26**) gave the cyclised products (**22**) 45% and (**27**) 45%, respectively (Scheme 2).

An alternative approach to heterocyclic synthesis involves the reaction of dimethyl allene-1,3-dicarboxylate (**1**) with substrates having adjacent nucleophilic and electrophilic groups. Mercaptobenzoic acid (**28**) readily undergoes Michael addition with the allene (**1**). The products (*E*)-2-(2-methoxycarbonyl-1-methoxycarbonylmethylvinyl)thiobenzoic acid (**29**) and (*Z*)-2-(2-methoxycarbonyl-1-methoxycarbonylmethylvinyl)thiobenzoic acid (**30**) then cyclised in two ways. In the first case both (**29**) and (**30**) were methylated to afford (**31**) and (**32**), respectively followed by cyclisation in the presence of potassium t-butoxide to give methyl 3-methoxycarbonyl-4-oxo-4*H*-[1]benzothiopyran-2-yl acetate (**33**) (37%). Alternatively, (**33**) was formed in better yield (54%) in one-step cyclisation of both (**29**) and (**30**) with polyphosphoric acid. Attempts to hydrolyse the diester (**33**) leads to hydrolysis and decarboxylation at the 2-position to give the 2-methylthiochromone (**34**) (63%) (Scheme 3). In addition both ethyl 2-amino-4,5,6,7-tetrahydrobenzo[*b*]thiophene-3-carboxylate (**35**) and ethyl 5-phenylthiophene-3-carboxylate (**38**) on reaction with the allene (**1**) gave the desired Michael adducts (**36**) and (**39**) which on cyclisation with sodium methoxide gave the pyridones (**37**) and (**40**), respectively. Both products (**37**) and (**40**) were alternatively synthesized in one step when reactants were refluxed in methanol in the presence of potassium t-butoxide (Schemes 4 and 5).

Reaction of 6-aminouracil (**41**) with dimethyl allene-1,3-dicarboxylate (**1**) is particularly interesting since Michael addition may either occur by attack of enamine carbon at C-5 on the



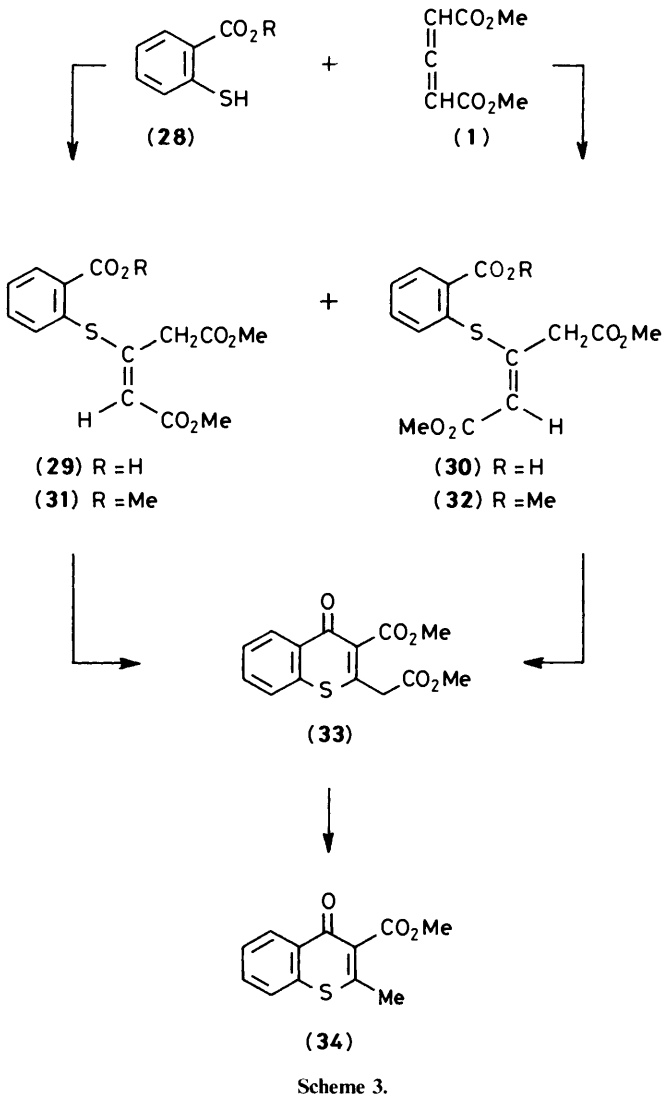
Scheme 2.

central carbon atom of dimethyl allene-1,3-dicarboxylate (**1**) or by addition of endocyclic or exocyclic nitrogen. 6-Aminouracil (**41**) with the allene (**1**) in refluxing water gave a compound readily identifiable by both ^{13}C and ^{1}H n.m.r. spectroscopy as a pyrido[2,3-*d*]pyrimidine (**44**) (62%) (Scheme 6). When the reaction was carried out in dry dimethyl sulphoxide the product was identified as (*E*)-dimethyl 3-(6-amino-1,2,3,4-tetrahydro-2,4-dioxopyrimidin-5-yl)pent-2-enedioate (**43**) (41%) and reaction in methanol gave the *Z*-isomer (**42**) (45%). The stereochemical assignments of the *Z*- and *E*-isomers (**42**) and (**43**) follow from ^{1}H chemical-shift studies of the methylene group located *cis* and *trans* to the methoxycarbonyl group. Thus the ester *cis* to the methylene group exerts a deshielding effect [15–17] and correlation studies show [18] that for the *E*-isomer the methylene resonance is in the range of δ 3.69—4.10 while for the *Z*-isomer it is δ 3.05—3.37. Thus we assigned the stereochemistry of compound (**43**) as *E* (δ 4.10 for CH_2) and (**42**) as *Z* (δ 3.20 for CH_2). When the two isomers (**42**) and (**43**) were heated in dimethylformamide, they readily and quantitatively cyclised to the pyrido[2,3-*d*]pyrimidine (**44**). 1-Methyl-6-aminouracil (**45**) also reacted with the allene (**1**) in refluxing water to give methyl 1,2,3,4,7,8-hexahydro-1-methyl-2,4,7-trioxopyrido[2,3-*d*]pyrimidin-5-yl acetate (**46**) (52%). It is interesting to note that 5-aminouracil under the same conditions, failed to react. Similarly Broom *et al.* [19] treated 6-aminouracil and its derivatives with dimethyl acetylenedicarboxylate (DMAD) and observed that Michael addition occurs by attack of C-5 on the triple bond of DMAD. Furthermore, Danishefsky and Etheridge [20] have also demonstrated that nucleophilic attack by enamine carbon is preferred to Michael addition of nitrogen in pyridone formation.

Experimental

Elemental analyses were carried out by Butterworth Laboratories. M.p.s were determined on a Kofler hot-stage microscope and both m.p.s and b.p.s are uncorrected. I.r. spectra were recorded on a Perkin-Elmer 257 grating spectrophotometer and ^{1}H n.m.r. spectra were measured on either a Varian EM 360 (60 MHz) or a Perkin-Elmer R32 (90 MHz). ^{13}C N.m.r. spectra were determined on a Varian CFT 20 (20 MHz) instrument. Low-resolution mass spectra were determined on a Kratos MS 30 single focussing spectrometer and high-resolution mass measurements were carried out on an AEI 902 S instrument. Medium-pressure chromatography [21] was carried out using Merck Kieselgel 60H, 'flash' chromatography [22] using Merck

Kieselgel 60, and analytical thin-layer chromatography with Camlab polygram SIL G/UV. All solvents were distilled before use.

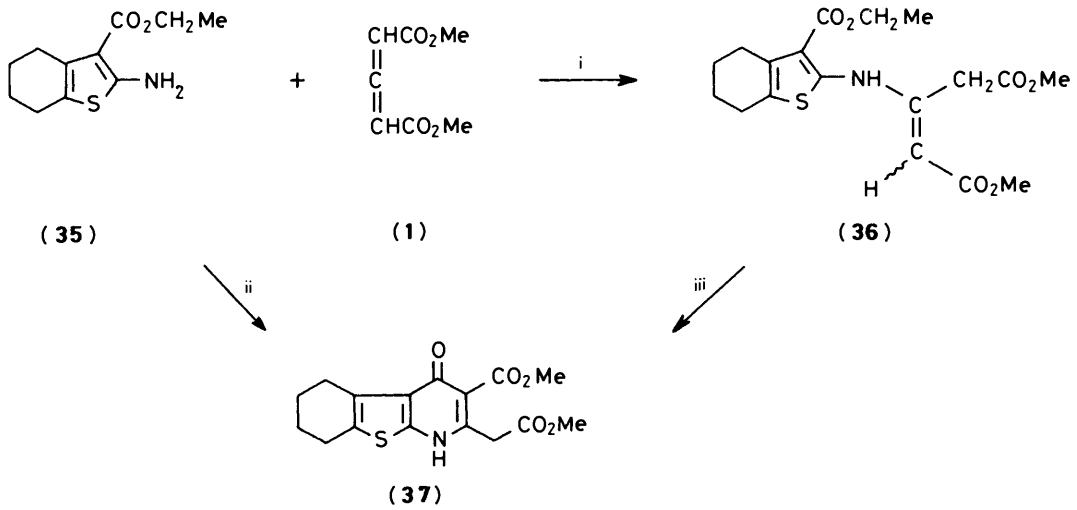


Scheme 3.

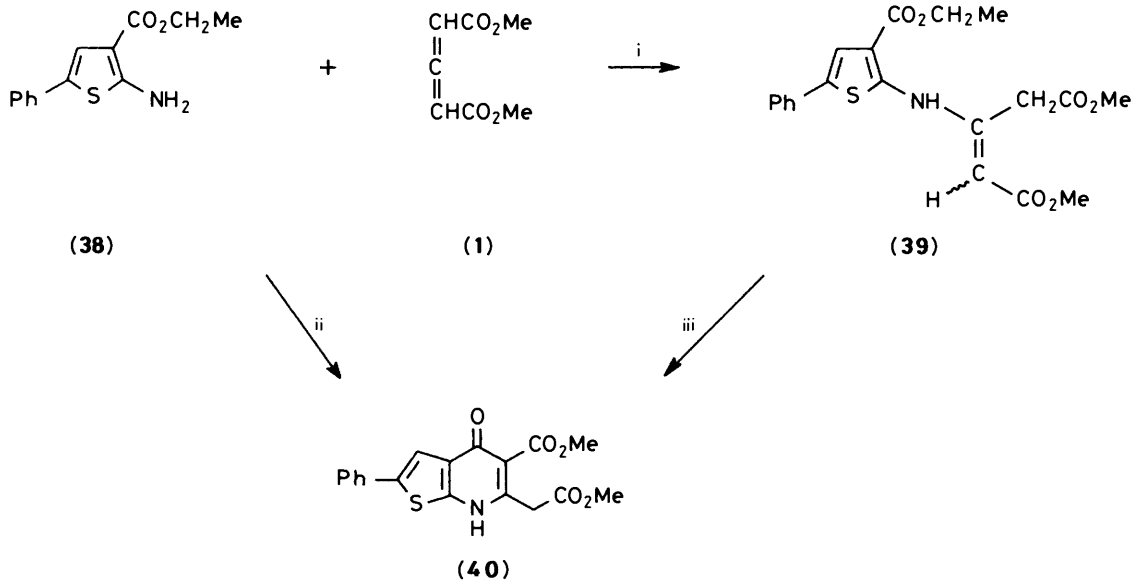
Preparation of Methyl 7-Oxo-7H-1,3,4-thiadiazolo[3,2-a]pyrimidin-5-ylacetate (**8**).—Dimethyl penta-2,3-dienedioate (**1**)[23] (1.56 g, 10 mmol) was added to a solution of 2-amino-1,3,4-thiadiazole (**2**) (1.01 g, 10 mmol) in dry methanol (50 cm^3) at −45 °C under an argon atmosphere. The resulting mixture was stirred for 20 min, refluxed for 12 h, and then concentrated under reduced pressure to afford an off-white residue which after recrystallisation from dimethylformamide gave the *title compound* (**8**) as a white solid (1.15 g, 51%), m.p. 175—177 °C; $\nu_{max.}$(Nujol) 1 730, 1 660, and 1 610 cm^{-1}; δ_H[90 MHz; $(CD_3)_2SO$] 8.0 (1 H, s, CH), 6.6 (1 H, s, CH), 4.0 (2 H, s, CH_2), and 3.65 (3 H, s, OCH_3); δ_C[20 MHz; $(CD_3)_2SO$] 168.23 (s, C=O), 166.70 (s, C=O), 165.50 (s, C-2), 143.10 (s, C-6), 130.27 (d, C-13), 109.27 (d, C-5), 52.31 (q, OCH_3), and 39.67 (t, CH_2); *m/z* 226 ($M^+ + 1$), 225 (M^+), and 194 ($M^+ - 31$); *m/z* 226.0563 ($M + 1$), 225.0484 (M), and 194.0299 ($C_8H_8N_3O_3S$ requires $M + 1$, 226.0564; $C_8H_7N_3O_3S$ requires M, 225.0486; $C_7H_4N_3O_2S$ requires 194.0299) (Found: C, 42.8; H, 3.2; N, 18.7. $C_8H_7N_3O_3S$ requires C, 42.7; H, 3.1; N, 18.7%).

Preparation of Methyl 7-Oxo-7H-1,4-thiazolo[3,2-a]pyrimidin-5-ylacetate (**9**).—Dimethyl penta-2,3-dienedioate (**1**) (1.20 g, 7.69 mmol) was added to a solution of 2-aminothiazole (**3**) (0.77 g, 7.69 mmol) in dry methanol (30 cm^3). The resulting mixture was stirred overnight at room temperature (21 °C) under an argon atmosphere after which it was evaporated under reduced pressure to give a brown residue; this after washing with diethyl ether (35 cm^3) gave brown crystals which upon recrystallisation from dimethylformamide afforded the *title compound* (**9**) as an off-white crystalline solid (1.80 g, 67%), m.p. 167—169 °C; $\nu_{max.}$(Nujol) 1 730, 1 650, and 1 610 cm^{-1}; δ_H[90 MHz; $CDCl_3$–$(CD_3)_2SO$] 7.83 (1 H, d, 2-H), 7.3 (1 H, d, 3-H), 6.3 (1 H, s, 6-H), 4.1 (2 H, s, CH_2), and 3.77 (3 H, s, OCH_3); δ_C[20 MHz; $(CD_3)_2SO$] 168.13 (s, C=O), 166.65 (s, C=O), 165.41 (s, C-2), 142.60 (s, C-6), 123.56 (d, C-13), 111.96 (d, C-12), 109.28 (d, C-5), 52.28 (q, OCH_3), and 39.59 (t, CH_2); *m/z* 225 ($M^+ + 1$), 224 (M^+), 196 ($M^+ - 28$), 193 ($M^+ - 31$), and 165 ($M^+ - 59$); *m/z* 225.0610 ($M + 1$), 224.0530 (M), and 193.0348 ($C_9H_9N_2O_3S$ requires $M + 1$, 225.0611), $C_9H_8N_2O_3S$ requires M, 224.0533; $C_8H_5N_2O_2S$ requires 193.0350) (Found: C, 48.2; H, 3.6; N, 12.5. $C_9H_8N_2O_3S$ requires C, 48.2; H, 3.6; N, 12.5%).

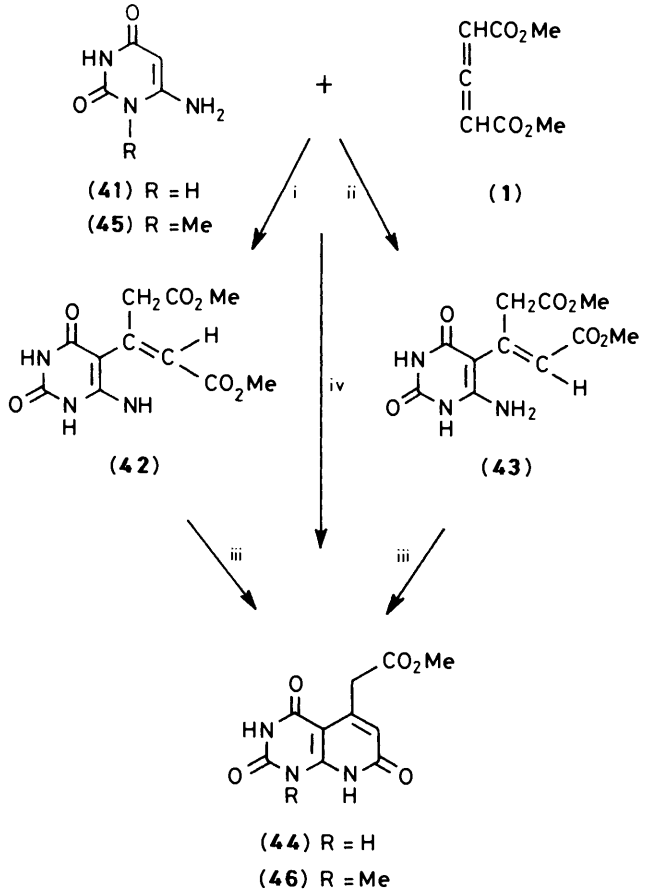
Preparation of Methyl 2-Oxo-2H-pyrimido[1,2-a]pyrimidin-4-ylacetate (**10**).—Dimethyl penta-2,3-dienedioate (**1**), (1.56 g, 10 mmol) was added to a solution of 2-aminopyrimidine (**4**)



Scheme 4. *Reagents:* i, MeOH; ii, KOBu^t, MeOH; iii, NaOMe



Scheme 5. *Reagents:* i, MeOH; ii, KOBu^t, MeOH; iii, NaOMe



Scheme 6. *Reagents:* i, MeOH; ii, dry Me_2SO; iii, reflux DMF; iv, H_2O

(1.23 g, 10 mmol) in dry methanol (50 cm^3) at −78 °C under an argon atmosphere. The resulting mixture was stirred for 16 h after which it was concentrated under reduced pressure to give a yellow precipitate which on recrystallisation from a mixture of methanol and dimethylformamide afforded the title compound (**10**) as a pale yellow solid, (1.27 g, 58%), m.p. 180 °C; $\nu_{max.}$(Nujol) 1 740, 1 648, and 1 600 cm^{-1}; δ_H[90 MHz; $CDCl_3$–$(CD_3)_2SO$] 8.25 (2 H, d, 2 × ArH), 7.85 (1 H, t, CH), 6.5 (1 H, s, CH), 4.0 (2 H, s, CH_2), and 3.65 (3 H, s, OCH_3); δ_C[20 MHz; $(CD_3)_2SO$] 169.12 (s, C=O), 168.0 (s, C=O), 152.12 (s, C-2), 143.21 (s, C-10), 136.50 (d, C-6), 124.21 (d, C-5), 118.36 (d, C-4, 113.60 (d, C-9), 52.01 (q, OCH_3), and 37.21 (t, CH_2); *m/z* 220 ($M^+ + 1$), 219 (M^+), and 188 ($M^+ - 31$); *m/z* 219.0640 (*M*) and 188.0459 ($C_{10}H_9N_3O_3$ requires *M*, 219.0642; $C_9H_6N_3O_2$ requires 188.0459) (Found: C, 54.8; H, 4.2; N, 19.2. $C_{10}H_9N_3O_3$ requires C, 54.8; H, 4.1; N, 19.2%).

*Preparation of Methyl 2-Oxo-*2H*-pyrido*[1,2-a]*pyrimidin-*4*-ylacetate* (**11**).—Dimethyl penta-2,3-dienedioate (**1**) (1.56 g, 10 mmol) was added to a solution of 2-aminopyridine (**5**), (0.94 g, 10 mmol) in dry methanol (50 cm^3) under an argon atmosphere. The mixture was stirred at room temperature (21 °C) for 14 h to give a black mixture which was then evaporated under reduced pressure. The residue obtained was treated with acetone (50 cm^3) to give *methyl 2-oxo-*2H*-pyrido*[1,2-a]*pyrimidin-*4*-yl acetate* (**11**) as an off-white crystalline solid (1.52 g, 73%), m.p. 183—184 °C; $\nu_{max.}$(Nujol) 1 720, 1 640, 1 600, and 780 cm^{-1}; δ_H[90 MHz; $CDCl_3$–$(CD_3)_2SO$] 8.13 (1 H, d, 6-H), 7.62 (1 H, m, 5-H), 7.23 (1 H, d, 3-H), 6.90 (1 H, m, 4-H), 6.50 (1 H, s, 9-H), 4.2 (2 H, s, CH_2), and 3.7 (3 H, s, OCH_3); δ_C[20 MHz; $(CD_3)_2SO$] 168.26 (s, C=O), 167.18 (s, C=O), 152.12 (s, C-2), 142.83 (s, C-10), 136.29 (d, C-6), 130.28 (d, C-3), 123.70 (d, C-5), 117.60 (d, C-4), 112.60 (d, C-9), 52.18 (q, CH_3), and 36.60 (t, CH_2); *m/z* 219 ($M^+ + 1$), 218 (M^+), 190 ($M^+ - 28$), and 131 ($M^+ - 87$); *m/z* 218.0692 (*M*) and 131.0608 ($C_{11}H_{10}N_2O_3$ requires 218.0689; $C_8H_7N_2$ requires 131.0611) (Found: C, 60.4; H, 4.7; N, 12.8. $C_{11}H_{10}N_2O_3$ requires C, 60.5; H, 4.6; N, 12.8%).

Preparation of Methyl 2,10-*Dihydro-*2*-oxopyrimido*[1,2-a]*-benzimidazol-*4*-ylacetate* (**12**).—Freshly distilled dimethyl penta-2,3-dienedioate (**1**) (1.80 g, 12 mmol) was added to a warm solution of 2-aminobenzimidazole (**6**), (1.33 g, 10 mmol) in dry methanol (50 cm^3) under an argon atmosphere and the resulting mixture was stirred at room temperature (21 °C) for 15 min. The precipitate was filtered off, washed with light petroleum (b.p. 40—60 °C; 100 cm^3) and then recrystallised

from dimethylformamide to give the *title compound* (**12**) as a white crystalline solid (1.65 g, 76%), m.p. 243—245 °C; $\nu_{max.}$(Nujol) 1 720, 1 690, 1 610, 1 590, and 760 cm^{-1}; δ_H[90 MHz; $(CD_3)_2SO$] 7.6—7.0 (5 H, m, 4 × ArH and NH), 6.0 (1 H, s, 3-H), 4.3 (2 H, s, CH_2), and 3.62 (3 H, s, OCH_3); *m/z* 258 ($M^+ + 1$), 257 (M^+), 226 ($M^+ - 59$), and 184 ($M^+ - 73$); *m/z* 257.0709 (*M*), 226.0615, and 198.0666 ($C_{13}H_{11}N_3O_3$ requires 257.0798; $C_{12}H_8N_3O_2$ requires 226.0615; $C_{11}H_8N_3O$ requires 198.0666) (Found: C, 60.7; H, 4.3; N, 16.3. $C_{13}H_{11}N_3O_3$ requires C, 60.4; H, 4.4; N, 16.4%).

*Preparation of Methyl 2-Oxo-*2H*-pyrimido*[2,1-b]*benzothiazol-4-ylacetate* (**13**).—Dimethyl penta-2,3-dienedioate (**1**) (2.68 g, 170 mmol) was added to a solution of 2-aminobenzothiazole (**7**) (2.58 g, 170 mmol) in dry methanol (50 cm^3) and the resulting mixture was stirred at room temperature (21 °C) under an argon atmosphere for 18 h. The light-yellow precipitate was filtered off and recrystallised from methanol–dimethylformamide to give the *title compound* (**13**) as a light yellow crystalline solid (2.95 g, 63%), m.p. 223—225 °C; $\nu_{max.}$(Nujol) 1 730, 1 650, 1 600, 1 595, and 760 cm^{-1}; δ_H[90 MHz; $CDCl_3$–$(CD_3)_2SO$] 8.0—7.4 (4 H, m, 4 × ArH), 6.30 (1 H, s, 3-H), 4.4 (2 H, s, CH_2), and 3.67 (3 H, s, OCH_3); *m/z* 275 ($M^+ + 1$), 274 (M^+), 246 ($M^+ - 31$), and 215 ($M^+ - 59$); *m/z* 274.0686 (*M*) and 243.0508 ($C_{13}H_{10}N_2O_3S$ requires *M*, 274.0689 and $C_{12}H_7N_2O_2S$ requires 243.0506) (Found: C, 56.4; H, 3.7; N, 10.2. $C_{13}H_{10}N_2SO_3$ requires C, 56.9; H, 3.4; N, 10.2%).

Preparation of Methyl (3,6-*Dihydro-6-oxo-2-phenylpyrimidin-4-yl)acetate* (**15**).—Dimethyl penta-2,3-dienedioate (**1**) (1.56 g, 10 mmol) was added to a solution of benzamidine (**14**), (1.20 g, 10 mmol) in dry methanol (50 cm^3) and the resulting mixture was stirred at room temperature (22 °C) for 20 h under an argon atmosphere. The light-pink precipitate that formed was filtered off and recrystallised from methanol–dimethylformamide to give the *title compound* (**15**) as a light pink solid (1.02 g, 42%), m.p. 95—97 °C; $\nu_{max.}$(Nujol) 1 736, 1 660, and 1 610 cm^{-1}; δ_H[90 MHz; $(CD_3)_2SO$] 7.8—7.6 (6 H, m, 5 × ArH and NH), 5.93 (1 H, s, CH), 4.0 (2 H, s, CH_2), and 3.76 (3 H, s, OCH_3); δ_C[20 MHz; $(CD_3)_2SO$] 169.96 (s, C=O), 168.23 (s, C=O), 163.86 (s, C-4), 160.93 (s, C-2), 157.64 (s, C-5), 134.43 (s, C-1′), 131.27 (d, C-2′ and C-4′), 128.31 (d, C-3′ and C-5′), 127.61 (d, C-4′), 51.93 (q, OCH_3), and 39.59 (t, CH_2); *m/z* 245 ($M^+ + 1$), 244 (M^+), 213 ($M^+ - 31$), and 185 ($M^+ - 59$); *m/z* 244.0843 (*M*) ($C_{13}H_{12}N_2O_3$ requires *M*, 244.0845).

Preparation of Methyl (2-*Amino*-3,6-*dihydro*-6-*oxopyrimidin-4-yl)acetate* (**17**).—Sodium methoxide (0.54 g, 10 mmol) was added to a solution of guanidine hydrochloride (**16**) (0.95 g, 10 mmol) in dry methanol (35 cm^3) and the resulting mixture was stirred at room temperature (21 °C) under an argon atmosphere for 10 min. Dimethyl penta-2,3-dienedioate (**1**) (1.56 g, 10 mmol) was then gradually added and the mixture stirred for further 18 h at room temperature (21 °C). The mixture was diluted with water (15 cm^3) to give a reddish solution which on acidification with 2M acetic acid precipitated a solid. Recrystallisation of this from methanol–dimethylformamide gave the *title compound* (**17**) as a yellow solid (0.69 g, 38%), m.p. 87—89 °C; $\nu_{max.}$(Nujol) 3 450, 3 310, 1 740, and 1 680 cm^{-1}; δ_H[90 MHz; $CDCl_3$–$(CD_3)_2SO$] 10.83 (1 H, s, NH), 5.86 (1 H, s, CH), 5.62 (2 H, s, NH_2), 4.0 (2 H, s, CH_2), and 3.83 (3 H, s, OCH_3); *m/z* 184 ($M^+ + 1$), 183 (M^+), 152 ($M^+ - 31$), and 124 ($M^+ - 59$); *m/z* 183.0643, 167.0454, and 152.0460 ($C_7H_9N_3O_3$ requires *M*, 183.0641; $C_7H_7N_2O_3$ requires 167.0454; $C_6H_6N_3O_2$ requires 152.0458) (Found: C, 45.9; H, 5.0; N, 22.9. $C_7H_9N_3O_3$ requires C, 45.9; H, 5.0; N, 22.9%).

Preparation of (E)-*Dimethyl* 3-(1,4-*Dihydro*-4-*oxopyrimidin-2-ylthio)pent-2-enedioate* (**20**) *and* (Z)-*Dimethyl* 3-(1,4-*Dihydro-4-oxopyrimidin-2-ylthio)pent-2-enedioate* (**19**).—Dimethyl penta-2,3-dienedioate (**1**) (1.10 g, 7.04 mmol) was added to a solution of 2-thiouracil (**18**) (0.90 g, 7.04 mmol) in dry methanol (30 cm^3) and the resulting mixture was refluxed under an argon atmosphere for 13 h. Evaporation of the mixture under reduced pressure gave a white solid, which on examination by t.l.c., using a solvent system of 95% chloroform and 5% methanol showed two spots (R_F 0.21 and 0.17). The less polar component (R_F 0.21) was separated by medium-pressure column chromatography to give the *title compound* (**20**) as a pale yellow solid (1.04 g, 52%), m.p. 113—115 °C; $\nu_{max.}$(Nujol) 1 730 and 1 660 cm^{-1}; δ_H(90 MHz; $CDCl_3$) 8.0 (1 H, d, ArH), 6.35 (1 H, d, ArH), 5.95 (1 H, s, CH), 4.0 (2 H, s, CH_2), 3.75 (3 H, s, OCH_3), and 3.70 (3 H, s, OCH_3); *m/z* 253 ($M^+ - 31$), 252 ($M^+ - 32$), and 225 ($M^+ - 59$); *m/z* 253.0562 ($M - 31$) and 225.0611 ($C_{10}H_9N_2O_4S$ requires 253.0560; $C_9H_9N_2O_3$ requires 225.0611) (Found: C, 46.5; H, 4.3; N, 9.9. $C_{11}H_{12}N_2O_5S$ requires C, 46.5; H, 4.3; N, 9.9%).

The most polar component (R_F 0.17), the *title compound* (**19**) was then obtained as a yellow solid (0.9 g, 38%), m.p. 120—123 °C; $\nu_{max.}$(Nujol) 1 734 and 1 670 cm^{-1}; δ_H(90 MHz; $CDCl_3$) 8.10 (1 H, d, ArH), 6.4 (1 H, d, ArH), 6.1 (1 H, s, CH), 3.72 (3 H, s, OCH_3), 3.67 (3 H, s, OCH_3), and 3.20 (2 H, CH_2); *m/z* 253 ($M^+ - 31$) and 225 ($M^+ - 59$); *m/z* 253.0562 ($M - 31$) and 225.0609 ($C_{10}H_9N_2O_4S$ requires 253.0562; $C_9H_9N_2O_3S$ requires 225.0611 (Found: C, 46.5; H, 4.3; N, 9.9. $C_{11}H_{12}N_2O_5S$ requires C, 46.5; H, 4.3; N, 9.9%).

Preparation of Methyl 2,3-*dihydro*-3,5-*dioxo*-5H-*imidazo*[2,1-b][1,3]*thiazin-7-ylacetate* (**22**).—Dimethyl penta-2,3-dienedioate (**1**) (1.1 g, 7.04 mmol) was added to a solution of 2-thiohydantoin (**21**), (0.82 g, 7.04 mmol) in dry methanol (30 cm^3) and the resulting mixture was refluxed under an argon atmosphere for 18 h. Evaporation of the mixture gave a brown solid which on recrystallisation from dimethylformamide afforded the *title compound* (**22**) as a pale yellow solid (0.76 g, 45%), m.p. 112—114 °C; $\nu_{max.}$(Nujol) 1 760, 1 740, 1 720, and 1 610 cm^{-1}; δ_H[90 MHz; $(CD_3)_2SO$]; 6.55 (1 H, s, CH), 4.1 (2 H, s, CH_2), 4.0 (2 H, s, CH_2), and 3.65 (3 H, s, OCH_3); *m/z* 240 (M^+), 212 ($M^+ - 28$), 197 ($M^+ - 43$), and 181 ($M^+ - 59$); *m/z* 240.0480 (*M*) and 212.0533 ($C_7H_5N_2O_2S$ requires 181.0350) (Found: C, 45.0; H, 3.4; N, 11.7. $C_9H_8N_2O_4S$ requires C, 45.0; H, 3.4; N, 11.7%).

Preparation of (E)-*Dimethyl* 3-(1,3-*benzothiazol-2-ylthio)-pent-2-enedioate* (**24**) *and* (Z)-*Dimethyl* 3-(1,3-*Benzothiazol-2-ylthio)pent-2-enedioate* (**25**).—Freshly distilled dimethyl penta-2,3-dienedioate (**1**) (1.56 g, 10 mmol) was added to a warm solution of 2-mercaptobenzothiazole (**23**), (1.67 g, 10 mmol) in dry methanol (50 cm^3) and the resulting mixture was stirred at room temperature (21 °C) under an argon atmosphere for 13 h. Evaporation of the mixture gave a viscous oil (2.56 g, 79%) which on examination by t.l.c. and elution with light petroleum (b.p. 60—80 °C)–ethyl acetate (7:3), showed two spots (R_F 0.45 and 0.39). The less polar component (R_F 0.45) was obtained by flash chromatography to give the *title compound* (**24**) as a colourless oil (1.03 g, 40%); $\nu_{max.}$(neat) 1 720, 1 685, 1 600, 800, and 700 cm^{-1}; δ_H(90 MHz; $CDCl_3$) 8.1—7.8 (2 H, m, 2 × ArH), 7.6—7.4 (2 H, m, 2 × ArH), 6.4 (1 H, s, CH), 4.1 (2 H, s, CH_2), and 3.7 (6 H, s, 2 × OCH_3); δ_C(20 MHz; $CDCl_3$) 168.41 (s, 2 × C=O), 164.16 (s, C-2), 147.42 (s, C-9 and C-10), 136.45 (s, C-4), 126.19 (d, C-5 and C-8), 125.47 (d, C-6 and C-7), 121.80 (d, C-11), 51.78 (q, 2 × OCH_3), and 37.94 (t, CH_2); *m/z* 324 ($M^+ + 1$), 323 (M^+), 292 ($M^+ - 31$), and 264 ($M^+ - 59$); *m/z* 324.0917 ($M + 1$) and 292.0658 ($C_{14}H_{14}NO_4S_2$ requires $M + 1$, 324.0919; $C_{13}H_{10}NO_3S_2$ requires 292.0658).

The more polar component (R_F 0.39) was then obtained to give the *title compound* (**25**) as a colourless oil (1.07 g, 42%); $\nu_{max.}$(neat) 1 730, 1 675, 1 590, and 760 cm^{-1}; δ_H(90 MHz; $CDCl_3$) 8.2—7.9 (2 H, m, 2 × ArH), 7.7—7.4 (2 H, m, 2 × ArH), 6.15 (1 H, s, CH), 3.8, (3 H, s, OCH_3), 3.78 (3 H, s, OCH_3), 3.70 (3 H, s, OCH_3), and 3.53 (2 H, s, CH_2); δ(20 MHz; $CDCl_3$), 168.50 (s, 2 × C=O), 164.356 (s, C-2), 147.52 (s, C-9 and C-10), 136.51 (s, C-4), 126.17 (d, C-5 and C-8), 125.42 (d, C-6 and C-7), 121.78 (d, C-11), 51.74 (q, 2 × OCH_3), and 37.93 (t, CH_2); *m/z* 324 ($M^+ + 1$), 323 (M^+), and 292 ($M^+ - 31$); *m/z* 324.0918 ($M + 1$) ($C_{14}H_{14}NO_4S_2$ requires $M + 1$, 324.0919).

Preparation of Methyl 3-Amino-2-methylimino-4-oxo-1,3-thiazin-6-ylacetate (**27**).—Freshly distilled dimethyl penta-2,3-dienedioate (**1**) (1.56 g, 10 mmol) was added to a solution of 4-methylthiosemicarbazide (**26**) (1.05 g, 10 mmol) in dry methanol (40 cm^3) and the resulting mixture was stirred at room temperature (22 °C) under an argon atmosphere for 14 h. Evaporation of the mixture gave a yellow solid which on recrystallisation from methanol–dimethylformamide gave the *title compound* (**27**) as a pale yellow crystalline solid (1.03 g, 45%), m.p. 190—192 °C; $\nu_{max.}$(Nujol) 3 450, 1 724, and 1 640 cm^{-1}; δ_H[90 MHz; $CDCl_3$–$(CD_3)_2SO$] 6.91 (1 H, s, CH), 5.35 (2 H, s, NH_2), 4.0 (2 H, s, CH_2), 3.79 (3 H, s, OCH_3), and 3.30 (3 H, s, NCH_3); *m/z* 229 (M^+), 213 ($M^+ - 16$), 198 ($M^+ - 31$), 188 ($M^+ - 41$), 170 ($M^+ - 59$), and 156 ($M^+ - 73$); *m/z* 229.0520 (*M*), 213.0330, and 198.0337 ($C_8H_{11}N_3O_3S$ requires *M*, 229.0518; $C_8H_9N_2O_3S$ requires 213.0331; $C_7H_8N_3O_2S$ requires 198.0335) (Found: C, 41.9; H, 4.9; N, 18.3. $C_8H_{11}N_3O_3S$ requires C, 41.9; H, 4.8; N, 18.3%).

Preparation of (E)-2-(2-*Methoxycarbonyl*-1-*methoxycarbonylmethylvinylthio*)*benzoic Acid* (**29**) *and* (Z)-2-(2-*Methoxycarbonyl*-1-*methoxycarbonylmethylvinylthio*)*benzoic Acid* (**30**).—Dimethyl penta-2,3-dienedioate (**1**) (1.10 g, 7.04 mmol) was added to a solution of thiosalicyclic acid (**28**) (1.08 g, 7.04 mmol) in dry methanol (35 cm^3) and the reaction mixture was stirred under an argon atmosphere at room temperature (21 °C) for 14 h. Evaporation of the mixture under reduced pressure gave a viscous oil (1.90 g, 87%), examination of which by t.l.c., and elution with a solvent system of light petroleum (b.p. 60—80 °C)–ethyl acetate–acetic acid (85:14:1) showed two spots (R_F0.28 and 0.16). The less polar component (R_F 0.28) was separated by medium-pressure column chromatography to give the *title compound* (**29**) as a pale yellow flaky solid (0.90 g, 41%), m.p. 110—111 °C; $\nu_{max.}$(Nujol) 3 400, 1 730, 1 660, and 1 585 cm^{-1}; δ_H(90 MHz; $CDCl_3$) 10.3 (1 H, s, OH), 8.1—8.0 (1 H, m, ArH), 7.7—7.4 (3 H, m, 3 × ArH), 5.82 (1 H, s, CH), 3.87 (2 H, s, CH_2), 3.7 (3 H, s, OCH_3), and 3.65 (3 H, s, OCH_3); δ_C(20 MHz; $CDCl_3$), 170.41 (s, C=O), 169.42 (s, 2 × C=O), 165.01 (s, C-3), 152.22 (s, C-2), 134.98 (d, C-4), 132.79 (d, C-7), 132.58 (d, C-5), 131.58 (d, C-6), 128.64 (C-9), 52.00 (q, OCH_3), and 38.44 (t, CH_2); *m/z* 310 (M^+) and 279 ($M^+ - 31$); *m/z* 310.0489 (*M*; $C_{14}H_{14}O_6S$ requires *M*, 310.0489) (Found: C, 54.2; H, 4.6. $C_{14}H_{14}O_6S$ requires C, 54.2; H, 4.5%).

The most polar component (R_F 0.16) was then obtained to afford the *title compound* (**30**) as a pale yellow oil (0.82, 37%); $\nu_{max.}$(neat) 3 410, 1 736, 1 680, and 1 590 cm^{-1}; δ_H(90 MHz; $CDCl_3$) 8.4 (1 H, s, OH), 8.1—7.9 (1 H, m, ArH), 7.7—7.4 (3 H, m, 3 × ArH), 6.05 (1 H, s, CH), 3.75 (3 H, s, OCH_3), 3.55 (3 H, s, OCH_3), and 3.2 (2 H, s, CH_2); δ_C(20 MHz; $CDCl_3$) 170.51 (s, C=O), 169.28 (s, 2 × C=O), 165.87 (s, C-3), 151.95 (s, C-2), 137.42 (d, C-4), 131.81 (d, C-7), 130.94 (d, C-5), 130.74 (d, C-6), 129.37 (s, C-9), 126.19 (d, C-10), 51.98 (q, OCH_3), 51.13 (q, OCH_3), and 42.08 (t, CH_2); *m/z* 310 (M^+) and 279 ($M^+ - 31$); *m/z* 310.0489 (*M*) ($C_{14}H_{14}O_6S$ requires *M*, 310.0489) (Found: C, 54.2; H, 4.6. $C_{14}H_{14}O_6S$ requires C, 54.2; H, 4.5%).

Cyclisation of (E)-2-(2-*Methoxycarbonyl*-1-*methoxycarbonylmethylvinylthio*)*benzoic Acid* (**29**) *by using Polyphosphoric Acid*.—Compound (**29**) (0.81 g, 2.61 mmol) was heated at 100 °C in polyphosphoric acid (15 g) for 1 h and the yellow solution so obtained was added to water (100 cm^3) and extracted with diethyl ether (3 × 50 cm^3). The organic layers were combined, dried ($MgSO_4$), and evaporated under reduced pressure to give a yellow solid which was purified by medium-pressure column chromatography with light petroleum (b.p. 60—80 °C)–ethyl acetate (7:3) as eluant to give *methyl* 3-*methoxycarbonyl*-4-*oxo*-4H-[1]*benzothiopyran*-2-*ylacetate* (**33**) as a light yellow solid (0.40 g, 53%), m.p. 173—175 °C; R_F 0.51 [light petroleum (b.p. 60—80 °C)–ethyl acetate (3:1)]; $\nu_{max.}$(Nujol) 1 730, 1 657, 1 610, and 1 580 cm^{-1}; δ_H[90 MHz; $(CD_3)_2SO$] 8.4—8.3 (1 H, d, ArH), 8.0—7.6 (3 H, m, 3 × ArH), 3.82 (2 H, s, CH_2), 3.80 (3 H, s, OCH_3), and 3.70 (3 H, s, OCH_3); *m/z* 293 ($M^+ + 1$), 292 (M^+), and 261 ($M^+ - 31$); *m/z* 292.0401 (*M*) ($C_{14}H_{12}O_5S$ requires *M*, 292.0405) (Found: C, 57.5; H, 4.2. $C_{14}H_{12}O_5S$ requires C, 57.5; H, 4.1%).

Cyclisation of (Z)-2-(2-*Methoxycarbonyl*-1-*methoxycarbonylmethylvinylthio*)*benzoic Acid* (**30**).—Compound (**30**) (0.81 g, 2.61 mmol) was heated at 100 °C in polyphosphoric acid (15 g) for 1 h to give a brown mixture which was added to water (100 cm^3) and extracted with chloroform (3 × 75 cm^3). The combined extracts were dried ($MgSO_4$) and evaporated under reduced pressure to give a yellow solid which on purification by medium-pressure column chromatography with light petroleum (b.p. 60—80 °C)–ethyl acetate (7:3) as eluant gave compound (**33**) as a light yellow solid (0.43 g, 54%), identical with that described previously.

In addition, when a mixture of both *E*- and *Z*-isomers was treated with polyphosphoric acid in a similar way, the same compound, namely (**33**), was obtained.

Preparation of Methyl 2-Methyl-4-oxo-4H-[1]benzothiopyran-3-carboxylate (**34**).—Methyl 2-methyl-4-oxo-4*H*-[1]benzothiopyran-2-ylacetate (**33**) (1.0 g, 3.4 mmol) and 50% aqueous acetic acid (15 cm^3) were refluxed for 16 h under an argon atmosphere. Excess of acetic acid was evaporated under reduced pressure and the resulting residue was purified by medium-pressure column chromatography eluting with light petroleum (b.p. 60—80 °C)–ethyl acetate (4:1) to give the *title compound* (**34**) as a reddish flaky solid (0.5 g, 63%), m.p. 148—152 °C, R_F 0.64 [light petroleum (b.p. 60—80 °C)–ethyl acetate (4:1)]; $\nu_{max.}$(Nujol) 1 720, 1 660, 1 610, and 1 585 cm^{-1}; δ_H(90 MHz; $CDCl_3$) 8.65—8.40 (1 H, d, ArH), 7.7—7.5 (3 H, m, 3 × ArH), 3.95 (3 H, s, OCH_3), and 2.45 (3 H, s, CH_3); *m/z* 235 ($M^+ + 1$) 234 (M^+), and 203 ($M^+ - 31$); *m/z* 234.0348 (*M*) and 203.0166 ($C_{12}H_{10}O_3S$ requires 234.0350; $C_{11}H_7O_2S$ requires 203.0166) (Found: C, 61.6; H, 4.3. $C_{12}H_{10}O_3S$ requires C, 61.5; H, 4.3%).

Preparation of (E)-*Dimethyl* 3-(2-*Methoxycarbonylvinylthio*)*pent*-2-*enedioate* (**31**).—An ethereal solution of diazomethane was added to compound (**29**) (1.0 g, 3.23 mmol) in diethyl ether (20 cm^3) at 0 °C until the solution became yellow and the t.l.c. showed absence of starting material. The mixture was evaporated under reduced pressure and the resulting residue purified by medium-pressure column chromatography with light petroleum (b.p. 60—80 °C)–ethyl acetate (7:3) as eluant to give the *title compound* (**31**) as a pale yellow solid (0.85 g, 82%), m.p. 108—110 °C; R_F 0.58 [light petroleum (b.p. 60—80 °C)–ethyl acetate (7:3)]; $\nu_{max.}$ 1 727, 1 680, and 1 600 cm^{-1}; δ_H(90 MHz; $CDCl_3$) 7.95—7.80 (1 H, m, ArH), 7.7—7.4 (3 H, m, 3 × ArH), 5.75 (1 H, s, CH), 3.90 (3 H, s, OCH_3), 3.80 (2 H, s, CH_2), 3.70 (3 H, s, OCH_3), and 3.62 (3 H, s, OCH_3); δ_C(20 MHz; $CDCl_3$) 168.94 (s, C=O), 166.36 (s, C=O), 165.75 (s, C=O), 164.80

(s, C-3), 152.68 (s, C-2), 137.68 (d, C-4), 135.36 (d, C-7), 130.96 (d, C-5), 130.60 (d, C-6), 129.57 (s, C-10), 128.77 (s, C-9), 52.13 (q, 2 × OCH_3), 51.86 (q, OCH_3), and 38.21 (t, CH_2); *m/z* 325 ($M^+ + 1$), 324 (M^+), and 293 ($M^+ - 31$); *m/z* 324.0661 (*M*) ($C_{15}H_{16}O_6S$ requires *M*, 324.0663).

Cyclisation of (E)-*Dimethyl* 3-(2-*Methoxycarbonylvinylthio*)-*pent*-2-*enedioate* (**31**).—Potassium t-butoxide (0.4 g, 3.52 mmol) was added to a solution of the title compound (**31**) (1.14 g, 3.52 mmol) in t-butyl alcohol (20 cm^3) and the resulting deep-red solution was refluxed under an argon atmosphere for 12 h. The mixture was evaporated and examination of the residue by t.l.c. and elution with light petroleum (b.p. 60—80 °C)–ethyl acetate (7:3) showed only one major spot (R_F 0.51). Purification by medium-pressure column chromatography gave compound (**33**) as a light yellow solid (0.38, 37%), m.p. 173—175 °C, identical with the compound described previously.

Preparation of (Z)-*Dimethyl* 3-(2-*Methoxycarbonylvinylthio*)-*pent*-2-*enedioate* (**32**).—An ethereal solution of diazomethane was added to a solution of compound (**30**) (1.0 g, 3.23 mmol) in diethyl ether (30 cm^3) at 0 °C until the solution became yellow and t.l.c. showed absence of starting material. The mixture was evaporated and the residue was purified by medium-pressure column chromatography with light petroleum (b.p. 60—80 °C)–ethyl acetate (7:3) to give the *title compound* (**32**) as a pale yellow solid (0.80 g, 81%), m.p. 123—125 °C, R_F 0.5 with light petroleum (b.p. 60—80 °C)–ethyl acetate (7:3) as eluant, $\nu_{max.}$ 1 727, 1 660, and 1 610 cm^{-1}; δ_H(90 MHz; $CDCl_3$) 7.95—7.80 (1 H, m, ArH), 7.7—7.4 (3 H, m, 3 × ArH), 6.0 (1 H, s, CH), 3.90 (3 H, s, OCH_3), 3.74 (3 H, s, OCH_3), 3.52 (3 H, s, OCH_3), and 3.20 (2 H, s, CH_2); δ_C(20 MHz; $CDCl_3$) 168.95 (s, C=O), 166.36 (s, C=O), 165.75 (s, C=O), 164.83 (s, C-3), 152.67 (s, C-2), 137.70 (d, C-4), 135.35 (d, C-7), 130.96 (d, C-5), 130.60 (d, C-6), 129.55 (s, C-10), 128.77 (s, C-9), 52.18 (q, 2 × OCH_3), 51.88 (q, OCH_3), and 38.47 (t, CH_2); *m/z* 324 (M^+) and 293 ($M^+ - 31$); *m/z* 324.0661 (*M*) ($C_{15}H_{16}O_6S$ requires *M*, 324.0663).

Cyclisation of (Z)-*Dimethyl* 3-(2-*Methoxycarbonylvinylthio*)-*pent*-2-*enedioate* (**32**).—Potassium t-butoxide (0.4 g, 3.52 mmol) was added to a solution of the title compound (**32**) (1.14 g, 3.52 mmol) in t-butyl alcohol (20 cm^3) and the resulting deep red solution was refluxed under an argon atmosphere for 8 h after which it was evaporated and the resulting residue purified by medium-pressure column chromatography with light petroleum (b.p. 60—80 °C)–ethyl acetate (7:3) as eluant to give methyl 3-methoxycarbonyl-4-oxo-4*H*-[1]benzothiopyran-2-ylacetate (**33**) (0.35 g, 36%), m.p. 173—175 °C, identical with the compound described previously. In addition, when a mixture of compound (**31**) and (**32**) was treated with t-butyl alcohol and potassium t-butoxide, compound (**33**) was also obtained.

Preparation of a Mixture of (E)- *and* (Z)-*Dimethyl* 3-(3-*Ethoxycarbonyl*-4,5,6,7-*tetrahydro*-2-*benzo*[b]*thienylamino*)-*pent*-2-*enedioate* (**36**).—Freshly distilled dimethyl penta-2,3-dienedioate (**1**) (0.70 g, 4.48 mmol) was added to a solution of ethyl 2-amino-4,5,6,7-tetrahydrobenzo[*b*]thiophene-3-carboxylate (**35**)[24] (1.01 g, 4.48 mmol) in dry methanol (40 cm^3) and the resulting mixture was stirred at room temperature (21 °C) under an argon atmosphere for 14 h. Evaporation of the mixture gave a thick viscous oil which after purification by flash chromatography with light petroleum (b.p. 60—80 °C)–ethyl acetate (95:5) as eluant gave a mixture of the *title compounds* (**36**) as a red oil (1.69 g, 99%), R_F 0.15 [light petroleum (b.p. 60—80 °C) ethyl acetate (95:5)]; $\nu_{max.}$(neat) 3 450, 3 350, 1 740, and 1 670 cm^{-1}; δ_H(90 MHz; $CDCl_3$) 11.65 (1 H, s, NH), 10.40 (1 H, s, NH), 5.85 (1 H, s, CH), 5.2 (1 H, s, CH), 4.4—4.2 (4 H, m, 2 × CH_2); 4.0 (2 H, s, CH_2), 3.71—3.63 (12 H, m, 4 × OCH_3), 3.5 (2 H, s, CH_2), 2.85—2.40 (12 H, m, 6 × CH_2), 2.30—2.15 (4 H, m, 2 × CH_2), and 1.95—1.50 (6 H, m, 2 × CH_3); *m/z* 381 (M^+) and 350 ($M^+ - 31$); *m/z* 381.1241 (*M*) and 350.1057 ($C_{18}H_{23}NO_6S$ requires *M*, 381.1240; $C_{17}H_{20}NO_6S$ requires 350.1057).

Cyclisation of a Mixture of (E)- *and* (Z)-*Dimethyl* 3-(3-*Ethoxycarbonyl*-4,5,6,7-*tetrahydro*-2-*benzo*[b]*thienylamino*)-*pent*-2-*enedioate* (**36**).—A mixture of the title compounds (**36**) (1.24 g, 3.25 mmol) was refluxed with sodium methoxide [prepared from sodium (0.3 g, 13 mmol) and dry methanol (30 cm^3)] under an argon atmosphere for 2 h. The mixture was evaporated and the residue dissolved in ice–water (35 cm^3) and neutralised with 0.1M hydrochloric acid. The grey precipitate was filtered off and washed with water (75 cm^3), methanol (30 cm^3), and diethyl ether (45 cm^3) and then recrystallised from a mixture of methanol–dimethylformamide to give *methyl* (1,4,5,6,7,8-*hexahydro*-3-*methoxycarbonyl*-4-*oxo*[1]*benzothieno*[2,3-b]*pyridin*-2-*yl*)*acetate* (**37**), as a light creamy solid (0.76 g, 70%), m.p. 143—145 °C; $\nu_{max.}$(Nujol) 3 310, 1 740, and 1 670 cm^{-1}; δ_H[90 MHz; $(CD_3)_2SO$] 4.0 (2 H, s, CH_2), 3.80 (3 H, s, OCH_3), 3.65 (3 H, s, OCH_3), 3.50 (5 H, m, 2 × CH_2 and NH), and 2.80—2.70 (4 H, m, 2 × CH_2); *m/z* 335 (M^+) and 304 ($M^+ - 31$); *m/z* 335.0825 (*M*) ($C_{16}H_{17}NO_5S$ requires *M*, 335.0823) (Found: C, 57.3; H, 5.2; N, 4.2. $C_{16}H_{17}NO_5S$ requires C, 57.3; H, 5.1; N, 4.2%).

Preparation of Methyl (1,4,5,6,7,8-*Hexahydro*-3-*methoxycarbonyl*-4-*oxo*[1]*benzothieno*[2,3-b]*pyridin*-2-*yl*)*acetate* (**37**) *without Isolation of the Enamine Intermediate* (**36**).—A solution of dimethyl penta-2,3-dienedioate (**1**) (1.56 g, 10 mmol) and ethyl 2-amino-4,5,6,7-tetrahydrobenzo[*b*]thiene-3-carboxylate (**35**)[24] (2.25 g, 10 mmol) in dry methanol (45 cm^3) was refluxed under an argon atmosphere for 2.5 h. Potassium t-butoxide (0.07 g) was then added and the mixture refluxed for further 2 h. The precipitate obtained, was filtered off, washed with methanol (30 cm^3), and then recrystallised from methanol–dimethylformamide to give the *title compound* (**37**) as a light creamy solid (1.86 g, 56%), m.p. 143—145 °C, identical with the compound prepared previously from (**36**).

Preparation of a Mixture of (E)- *and* (Z)-*Dimethyl* 3-(3-*Ethoxycarbonyl*-5-*phenyl*-2-*thienylamino*)*pent*-2-*enedioate* (**39**).—Freshly distilled dimethylpenta-2,3-dienedioate (**1**) (1.56 g, 10 mmol) was added to a solution of ethyl 2-amino-5-phenylthiophene-3-carboxylate (**38**)[24] (2.47 g, 10 mmol) in dry methanol (45 cm^3) and the resulting mixture was stirred at room temperature (22 °C) under an argon atmosphere for 12 h. Evaporation of the mixture gave a thick viscous oil which after purification by flash chromatography and elution with light petroleum (b.p. 60—80 °C)–ethyl acetate (4:1) gave the *title compounds* (**39**) as a colourless oil (4.0 g, 99%); R_F 0.34 [light petroleum (b.p. 60—80 °C)–ethyl acetate (4:1)]; $\nu_{max.}$(neat) 3 420, 3 350, 1 740, 1 680, 1 600, and 760 cm^{-1}; δ_H(90 MHz; $CDCl_3$) 11.57 (1 H, s, NH), 10.60 (1 H, s, N*H*), 7.8—7.3 (10 H, m, 10 × ArH), 6.9 (2 H, s, CH), 5.87 (1 H, s, CH), 5.18 (1 H, s, CH), 4.38—4.18 (4 H, m, 2 × CH_2), 4.0 (2 H, s, CH_2), 3.71—3.65 (12 H, m, 4 × OCH_3), 3.52 (2 H, s, CH_2), and 2.05—1.76 (6 H, m, 2 × CH_3); *m/z* 403 (M^+) and 372 ($M^+ - 31$); *m/z* 403.1085 (*M*) and 372.0903 ($C_{20}H_{21}NO_6S$ requires *M*, 403.1084. $C_{19}H_{18}NO_5S$ requires 372.0902).

Cyclisation of a Mixture of (E)- *and* (Z)-*Dimethyl* 3-(3-*Ethoxycarbonyl*-5-*phenyl*-2-*thienylamino*)*pent*-2-*enedioate* (**39**).—A mixture of the title compounds (**39**) (1.31 g, 3.25 mmol) was refluxed with sodium methoxide [prepared from sodium (0.3 g, 13 mmol) and dry methanol (30 cm^3)], under an argon atmosphere for 2 h. The mixture was evaporated under reduced

pressure and the residue was dissolved in ice–water (35 cm^3) and then neutralised with 0.1M hydrochloric acid. The precipitate was filtered off, washed with water (75 cm^3), methanol (35 cm^3), and diethyl ether (40 cm^3), and then recrystallised from methanol–dimethylformamide to give *methyl* (4,5,6,7-*tetrahydro*-5-*methoxycarbonyl*-4-*oxo*-2-*phenylthieno*[2,3-b]*pyridin*-6-*yl*)*acetate* (**40**) as a pale yellow crystalline solid (0.66 g, 56%), m.p. 142—144 °C; $\nu_{max.}$(Nujol) 3 315, 1 730, 1 670, 1 595, and 770 cm^{-1}; δ_H[90 MHz; $(CD_3)_2SO$] 10.47 (1 H, s, NH), 7.8—7.5 (5 H, m, 5 × ArH), 6.9 (1 H, s, CH), 4.0 (2 H, s, CH_2), 3.83 (3 H, s, OCH_3), and 3.65 (3 H, s, OCH_3); *m/z* 357 (M^+) and 326 ($M^+ - 31$); *m/z* 357.0668 (*M*), 326.0484, and 298.0537 ($C_{18}H_{15}NO_5S$ requires *M*, 357.0667; $C_{17}H_{12}NO_4S$ requires 326.0484; $C_{16}H_{12}NO_3S$ requires 298.0537) (Found: C, 60.5; H, 4.3; N, 3.9. $C_{18}H_{15}NO_5S$ requires C, 60.5; H, 4.2; N, 3.9%).

Preparation of Methyl (4,5,6,7-*Tetrahydro*-5-*methoxycarbonyl*-4-*oxo*-2-*phenylthieno*[2,3-b]*pyridin*-6-*yl*)*acetate* (**40**) *without Isolation of the Enamine Intermediate* (**39**).—A solution of dimethyl penta-2,3-dienedioate (**1**) (1.56 g, 10 mmol) and ethyl 2-amino-5-phenylthiophene-3-carboxylate (**38**),[24] (2.47 g, 10 mmol) in dry methanol (45 cm^3) was refluxed under an argon atmosphere for 2.5 h. Potassium t-butoxide (0.07 g) was then added and the mixture refluxed for a further 2 h. The precipitate was washed with methanol (30 cm^3) and then recrystallised from methanol–dimethylformamide to give the *title compound* (**40**) as a pale yellow crystalline solid (1.70 g, 48%), m.p. 142—144 °C, identical with the compound described previously.

Preparation of Methyl 1,2,3,4,7,8-*Hexahydro*-2,4,7-*trioxopyrido*[2,3-d]*pyrimidin*-5-*ylacetate* (**44**).—Dimethyl penta-2,3-dienedioate (**1**) (1.10 g, 7.04 mmol) was added to a suspension of 6-aminouracil (**41**) (0.89 g, 7.04 mmol) in distilled water (30 cm^3) and the resulting mixture was refluxed under an argon atmosphere for 10 h. The suspension obtained was cooled and filtered to give a white solid, which was recrystallised from aqueous dimethylformamide to give the *title compound* (**44**) as a white powder (1.10 g, 62%), m.p. 325 °C (decomp.); $\nu_{max.}$(Nujol) 1 730 and 1 665 cm^{-1}; δ_H[90 MHz; $CDCl_3$–$(CD_3)_2SO$] 11.80 (3 H, s, 3 × NH), 6.32 (1 H, s, CH), 4.05 (2 H, s, CH_2), and 3.65 (3 H, s, OCH_3); δ_C[20 MHz; $(CD_3)_2SO$] 170.32 (s, C=O), 165.09 (s, C-2), 162.28 (s, C-4), 152.52 (s, C-7), 149.94 (s, C-10), 149.21 (s, C-9), 110.16 (d, C-6), 99.14 (s, C-5), 51.56 (q, OCH_3), and 37.43 (t, CH_2); *m/z* 251 (M^+) and 220 ($M^+ - 31$); *m/z* 251.0541 (*M*) and 220.0342 ($C_{10}H_9N_3O_5$ requires *M*, 251.0542; $C_9H_6N_3O_4$ requires 220.0353) (Found: C, 47.6; H, 3.9; N, 16.7. $C_{10}H_9N_3O_5$ requires C, 47.8; H, 3.6; N, 16.7%).

Preparation of (Z)-*Dimethyl* 3-(6-*Amino*-1,2,3,4-*tetrahydro*-2,4-*dioxopyrimidin*-5-*yl*)*pent*-2-*enedioate* (**42**).—Dimethyl penta-2,3-dienedioate (**1**) (1.10 g, 7.04 mmol) and 6-aminouracil (**41**) (0.89 g, 7.04 mmol) were stirred in dry methanol (30 cm^3) for 5 days. On evaporation of solvent under reduced pressure the residue was thoroughly triturated with diethyl ether (120 cm^3) and filtered off to give the *title compound* (**42**) as a white powder (0.89 g, 45%), m.p. 320 °C (decomp.); $\nu_{max.}$(Nujol) 3 450 and 1 730 cm^{-1}; δ_H[90 MHz; $(CD_3)_2SO$] 10.40 (1 H, s, NH), 10.12 (1 H, s, NH), 6.70 (1 H, s, CH), 6.20 (2 H, s, NH_2), 3.75 (3 H, s, OCH_3), 3.65 (3 H, s, OCH_3), and 3.40 (2 H, s, CH_2); *m/z* 283 (M^+) and 252 ($M^+ - 31$); *m/z* 283.0803 (*M*) and 252.0618 ($C_{11}H_{13}N_3O_6$ requires *M*, 283.0801; $C_{10}H_{10}N_3O_5$ requires 252.0618) (Found: C, 46.6; H, 4.7; N, 14.8. $C_{11}H_{13}N_3O_6$ requires C, 46.6; H, 4.6; N, 14.8%).

Cyclisation of (Z)-*Dimethyl* 3-(6-*Amino*-1,2,3,4-*tetrahydro*-2,4-*dioxopyrimidin*-5-*yl*)*pent*-2-*enedioate* (**42**).—The title compound (**42**) (0.89 g, 3.14 mmol) in dry dimethylformamide (50 cm^3) was refluxed for 30 min under an argon atmosphere. Evaporation of the mixture gave a white solid which on recrystallisation from aqueous dimethylformamide gave compound (**44**) as a white powder (0.60 g, 76%), m.p. 325 °C (decomp.) identical with the product described previously.

Preparation of (E)-*Dimethyl* 3-(6-*Amino*-1,2,3,4-*tetrahydro*-2,4-*dioxopyrimidin*-5-*yl*)*pent*-2-*enedioate* (**43**).—6-Aminouracil (**41**) (0.89 g, 7.04 mmol) was dissolved in dry dimethyl sulphoxide (30 cm^3) and dimethyl penta-2,3-dienedioate (**1**) (1.10 g, 7.04 mmol) added and the solution stirred at room temperature (21 °C) under an argon atmosphere for 18 h. Diethyl ether (300 cm^3) was added to the resulting solution which was then stored at 5 °C for 2 days. Filtration afforded a solid, which after recrystallisation from aqueous dimethylformamide gave the title compound (**43**) as a white solid (0.79 g, 41%), m.p. 320 °C (decomp.); $\nu_{max.}$(Nujol) 3 450, 1 730, and 1 660 cm^{-1}; δ_H[90 MHz; $(CD_3)_2SO$] 10.55 (1 H, s, NH), 10.20 (1 H, s, NH), 6.65 (2 H, s, NH_2), 5.95 (1 H, s, CH), 4.10 (2 H, s, CH_2), 3.65 (3 H, s, OCH_3), and 3.60 (3 H, s, OCH_3); *m/z* 283 (M^+) and 252 ($M^+ - 31$); *m/z* 283.0803 (*M*) ($C_{11}H_{13}N_3O_6$ requires *M*, 283.0801) (Found: C, 46.6; H, 4.9; N, 14.9. $C_{11}H_{13}N_3O_6$ requires C, 46.6; H, 4.61; N, 14.8%).

Cyclisation of (E)-*Dimethyl* 3-(6-*Amino*-1,2,3,4-*tetrahydro*-2,4-*dioxopyrimidin*-5-*yl*)*pent*-2-*enedioate* (**43**).—A solution of

Table 1. Crystal data, details of intensity measurements, and structure refinement for the pyridones (**9**) and (**11**)

Complex	(**9**)	(**11**)
Formula	$C_9H_8N_2O_3S$	$C_{11}H_{10}N_2O_3{\cdot}H_2O$
M	224.24	236.23
Crystal system	Orthorhombic	Monoclinic
Space group	*Pna*2_1 (No. 33)	$P2_1/c$ (No. 14)
a/Å	10.660(4)	5.176(2)
b/Å	10.802(1)	16.377(8)
c/Å	8.284(3)	13.151(3)
β/°		95.92(2)
U/Å^3	954	1 109
Z	4	4
D_c/g cm^{-3}	1.561	1.415
F(000)	464	496
Crystal system/mm	0.50 × 0.25 × 0.13	0.85 × 0.50 × 0.38
μ/cm^{-1}	28.94	8.79
Absorption correction (min., max.)	0.82, 1.00	0.95, 1.00
θ-Range	3.0, 70.0	3.0, 70.0
h-Range	0—10	−6—6
k-Range	0—13	0—19
l-Range	0—13	0—15
Intensity variation	<2%	<2%
Table no. of reflections	1 078	2 435
No. of unique reflections	967	2 100
Significance test	$F_o > 6\sigma(F_o)$	$F_o > 6\sigma(F_o)$
No. of reflections used in the refinement	902	1 943
No. of refined parameters	167	157
Max. least-squares shift-to-error ratio	0.001	0.001
Min. and max. height in final difference Fourier Map, *p*/e Å^{-3}	−0.19, 0.14	−0.26, 0.41
Function minimized	$\Sigma_w(\|F_o\| - \|F_c\|)^2$	$\Sigma_w(\|F_o\| - \|F_c\|)^2$
Weighting scheme parameter *g* in $w = 1/[\sigma^2(F) + gF^2]$	0.004	0.006
Final *R*	0.027	0.055
Final R_w	0.030	0.085

Table 2. Fractional atomic co-ordinates ($\times 10^4$) for compound (**9**)

	x	*y*	*z*
S	511(1)	3 264(1)	6 464
O(1)	4 339(2)	3 398(2)	9 851(3)
O(2)	1 381(2)	7 824(2)	8 663(3)
O(3)	2 634(2)	9 192(2)	7 402(3)
N(1)	2 585(2)	3 310(2)	8 309(3)
N(2)	1 914(2)	5 147(2)	6 940(3)
C(1)	2 927(2)	5 826(2)	7 546(3)
C(2)	3 714(2)	5 242(2)	8 549(4)
C(3)	3 592(2)	3 939(2)	8 959(3)
C(4)	1 823(2)	3 929(2)	7 369(3)
C(5)	146(3)	4 667(3)	5 560(4)
C(6)	956(2)	5 554(2)	5 923(3)
C(7)	3 114(2)	7 138(2)	7 000(4)
C(8)	2 258(2)	8 057(2)	7 810(3)
C(9)	1 857(3)	10 213(3)	7 929(5)

Table 3. Fractional atomic co-ordinates ($\times 10^4$) for compound (**11**)

	x	*y*	*z*
O(1)	3 912(3)	3 572(1)	6 893(1)
O(2)	−687(3)	4 186(1)	10 614(1)
O(3)	2 636(3)	4 399(1)	11 819(1)
O(4)	2 542(4)	368(1)	10 173(2)
N(1)	518(3)	2 646(1)	9 256(1)
N(2)	938(3)	2 714(1)	7 464(1)
C(1)	2 860(4)	3 281(1)	7 624(1)
C(2)	3 659(4)	3 528(1)	8 671(1)
C(3)	2 518(3)	3 225(1)	9 458(1)
C(4)	−722(3)	2 310(1)	10 043(1)
C(5)	−2 679(4)	1 763(1)	9 855(1)
C(6)	−3 464(4)	1 528(1)	8 836(2)
C(7)	−2 261(4)	1 847(1)	8 072(1)
C(8)	−177(3)	2 422(1)	8 250(1)
C(9)	3 343(3)	3 464(1)	10 543(1)
C(10)	1 485(3)	4 053(1)	10 971(1)
C(11)	1 106(5)	4 989(2)	12 330(2)

the title compound (**43**) (0.89 g, 3.14 mmol) in dry dimethylformamide (50 cm^3) was refluxed for 30 min under an argon atmosphere. Evaporation of the mixture under reduced pressure gave a solid which on recrystallisation from aqueous dimethylformamide afforded compound (**44**) as a white powder (0.35 g, 44%), m.p. 325 °C (decomp.), identical with the product described previously.

Preparation of Dimethyl 2,3,4,7,8-*Pentahydro*-2,4,7-*trioxopyrido*[2,3-d]*pyrimidin*-5-*ylacetate* (**46**).—Dimethyl penta-2,3-dienedioate (**1**) (1.10 g, 7.04 mmol) was added to a suspension of methyl 6-aminouracil (**45**) (0.99 g, 7.04 mmol) in water (30 cm^3) and the resulting mixture was refluxed under an argon atmosphere for 16 h. The yellow solution obtained was cooled and filtered off to give a solid which recrystallised from aqueous ethanol to afford the *title compound* (**46**) as a white (0.97 g, 52%), m.p. 300 °C (decomp.); $\nu_{max.}$(Nujol) 1 730 and 1 650 cm^{-1}; δ_H[90 MHz; $(CD_3)_2SO$] 11.50 (1 H, s, NH), 10.95 (1 H, s, NH), 6.50 (1 H, s, CH), 4.10 (2 H, s, CH_2), 3.8 (3 H, s, OCH_3), and 3.40 (3 H, s, NCH_3); δ_C[20 MHz; $(CD_3)_2SO$] 171.35 (s, C=O), 167.06 (s, C-2), 163.21 (s, C-4), 154.52 (s, C-7), 149.97 (s, C-10), 149.20 (s, C-9), 110.13 (d, C-6), 99.53 (s, C-5), 58.50 (q, NCH_3), 52.50 (q, OCH_3), and 37.60 (t, CH_2); *m/z* 265 (M^+) and 234 ($M^+ - 31$); *m/z* 265.0693 ($C_{11}H_{11}N_3O_5$ requires *M*,265.0696) (Found: C, 49.7; H, 4.2; N, 15.9. $C_{11}H_{11}N_3O_5$ requires C, 49.8; H, 4.2; N, 15.8%).

Crystallography.—Unit-cell parameters and intensity data were obtained by following previously detailed procedures,[25] using a CAD4 diffractometer operating in the ω—2θ scan mode, with Ni-filtered Cu-K_α radiation (λ = 1.5418 Å). The reflection intensities for both structures were corrected for absorption, using the azimuthal-scan method.[26] The relevant experimental data are summarized in Table 1.

The structures were solved by the application of routine direct method procedures (SHELX84[27]), and refined by full-matrix least-squares (SHELX76[28]). For (**11**), a single, isolated peak, was located in a difference Fourier synthesis. This was assumed to be the oxygen atom of a solvent water molecule [O(4) in Table 3, U = 0.07 $Å^2$]. The final cycle of refinement for (**11**) included all non-solvent hydrogen atoms in their calculated positions (C–H 0.96 Å, U = 0.10 $Å^2$), while for (**9**) all hydrogens were allowed unrestricted isotropic refinement. All the non-hydrogen atoms of both structures were refined with anisotropic thermal parameters.

All computations were made on a DEC VAX-11/750 com-

Table 4. Bond lengths (Å) and angles (°) for compound (**9**)

Bond lengths			
C(4)–S	1.742(4)	C(5)–S	1.735(5)
C(3)–O(1)	1.234(4)	C(8)–O(2)	1.199(4)
C(8)–O(3)	1.333(4)	C(9)–O(3)	1.446(4)
C(3)–N(1)	1.380(4)	C(4)–N(1)	1.308(4)
C(1)–N(2)	1.398(4)	C(4)–N(2)	1.366(4)
C(6)–N(2)	1.395(4)	C(2)–C(1)	1.339(5)
C(7)–C(1)	1.501(5)	C(3)–C(2)	1.453(4)
C(6)–C(5)	1.324(5)	C(8)–C(7)	1.506(5)
Bond angles			
C(5)–S–C(4)	90.3(2)	C(9)–O(3)–C(8)	116.9(3)
C(4)–N(1)–C(3)	117.6(3)	C(4)–N(2)–C(1)	117.8(3)
C(6)–N(2)–C(1)	128.1(3)	C(6)–N(2)–C(4)	114.1(3)
C(2)–C(1)–N(2)	117.4(3)	C(7)–C(1)–N(2)	119.3(3)
C(7)–C(1)–C(2)	123.2(3)	C(3)–C(2)–C(1)	123.0(3)
N(1)–C(3)–O(1)	120.1(3)	C(2)–C(3)–O(1)	122.8(3)
C(2)–C(3)–N(1)	117.1(3)	N(1)–C(4)–S	122.9(3)
N(2)–C(4)–S	110.0(3)	N(1)–C(4)–N(1)	127.0(3)
C(6)–C(5)–S	112.8(3)	C(5)–C(6)–N(2)	112.8(3)
C(8)–C(7)–C(1)	114.1(3)	O(3)–C(8)–O(2)	125.2(3)
C(7)–C(8)–O(2)	126.6(3)	C(7)–C(8)–O(3)	108.1(3)

Table 5. Bond lengths (Å) and angles (°) for compound (**11**)

Bond lengths			
C(1)–O(1)	1.247(3)	C(10)–O(2)	1.193(3)
C(10)–O(3)	1.334(3)	C(11)–O(3)	1.457(4)
C(3)–N(1)	1.408(3)	C(4)–N(1)	1.387(3)
C(8)–N(1)	1.385(3)	C(1)–N(2)	1.362(3)
C(8)–N(2)	1.324(3)	C(2)–C(1)	1.453(3)
C(3)–C(2)	1.339(3)	C(9)–C(3)	1.498(3)
C(5)–C(4)	1.356(3)	C(6)–C(5)	1.413(4)
C(7)–C(6)	1.342(4)	C(8)–C(7)	1.433(4)
C(10)–C(9)	1.511(4)		
Bond angles			
C(11)–O(3)–C(10)	116.7(3)	C(4)–N(1)–C(3)	120.9(2)
C(8)–N(1)–C(3)	118.2(2)	C(8)–N(1)–C(4)	120.9(2)
C(8)–N(2)–C(1)	119.7(3)	N(2)–C(1)–O(1)	120.8(3)
C(2)–C(1)–O(1)	121.3(3)	C(2)–C(1)–N(2)	117.9(3)
C(3)–C(2)–C(1)	121.6(3)	C(2)–C(3)–N(1)	118.5(2)
C(9)–C(3)–N(1)	119.2(2)	C(9)–C(3)–C(2)	122.3(3)
C(5)–C(4)–N(1)	121.3(3)	C(6)–C(5)–C(4)	119.4(3)
C(7)–C(6)–C(5)	119.6(3)	C(8)–C(7)–C(6)	122.3(3)
N(2)–C(8)–N(1)	124.0(3)	C(7)–C(8)–N(1)	116.6(3)
C(7)–C(8)–N(2)	119.4(3)	C(10)–C(9)–C(3)	113.1(2)
O(3)–C(10)–O(2)	125.0(3)	C(9)–C(10)–O(2)	125.4(3)
C(9)–C(10)–O(3)	109.6(2)		

puter. Fractional atomic co-ordinates are given in Tables 2, compound (**9**), and 3, compound (**11**), whilst bond lengths and angles are given in Tables 4, compound (**9**), and 5 compound (**11**). Hydrogen atomic co-ordinates and thermal parameters are available, on request, from the Cambridge Crystallographic Data Centre.*

Acknowledgements

We thank the S.E.R.C. for a studentship (to G. J. S. D.) and support of the *X*-ray work and the Nigerian Government for a grant (to D. I. O.). We also thank Mr. W. J. Kuil of Groningen University for drawing the reaction schemes.

* See 'Instructions for Authors 1988,' *J. Chem. Soc., Perkin Trans. 1*, 1988, Issue 1.

References

1 Part 6, G. J. S. Doad, U. Jordis, M. Rudolf, F. Sauter, and F. Scheinmann, *J. Chem. Res.*, 1986, (*S*), 410.
2 N. S. Nixon, F. Scheinmann, and J. L. Suschitzky, *J. Chem. Res.*, 1984, (*S*), 380; (*M*), 3401.
3 A. Shafiec and I. Lalezari, *J. Heterocycl. Chem.*, 1975, **12**, 675.
4 H. Reimlinger, *Chem. Ber.*, 1971, **104**, 2232.
5 M. N. Sharma, *Curr. Sci.*, 1974, **43**, 179.
6 G. R. Lappin, *J. Org. Chem.*, 1961, **26**, 2350.
7 I. J. Pachter, *J. Org. Chem.*, 1961, **26**, 4157.
8 J. G. Wilson and W. Bottomley, *J. Heterocycl. Chem.*, 1967, **4**, 360.
9 F. Troxler and H. Weber, *Helv. Chem. Acta*, 1974, **57**, 2356.
10 H. Ogura, M. Kawano, and T. Itah, *Chem. Pharm. Bull.*, 1973, **21**, 2019.
11 D. W. Dunwell and D. Evans, *J. Chem. Soc. C*, 1971, 2094.
12 S. Ruhemann and H. E. Stapleton, *J. Chem. Soc.*, 1900, **77**, 239.
13 J. W. Lown and J. C. N. Ma, *Can. J. Chem.*, 1967, **45**, 953.
14 J. Ackroyd and F. Scheinmann, *J. Chem. Res.*, 1982, (*S*), 89; (*M*), 1012.
15 E. Winterfeldt and J. M. Nelke, *Chem. Ber.*, 1968, **101**, 2381.
16 L. M. Jackman and R. H. Wiley, *Proc. Chem. Soc.*, 1958, 197.
17 L. M. Jackman and R. H. Wiley, *J. Chem. Soc.*, 1960, 2887.
18 N. S. Nixon, Ph.D. Thesis, University of Salford, 1983.
19 A. D. Broom, J. L. Shim, and G. L. Anderson, *J. Org. Chem.*, 1976, **41**, 1095.
20 S. Danishefsky and S. J. Etheredge, *J. Org. Chem.*, 1974, **39**, 3430.
21 B. J. Hunt and W. Rigby, *Chem. Ind. (London)*, 1967, 1868.
22 W. C. Still, M. Khan, and A. Mitra, *J. Org. Chem.*, 1978, **43**, 2923.
23 T. A. Bryson and T. M. Dolak, *Org. Synth.*, 1977, **57**, 62.
24 K. Gewald, E. Schinke, and H. Bottcher, *Chem. Ber.*, 1966, **99**, 94.
25 M. B. Hursthouse, R. A. Jones, K. M. A. Malik, and G. Wilkinson, *J. Am. Chem. Soc.*, 1979, **101**, 4128.
26 A. C. T. North, D. C. Phillips, and F. S. Mathews, *Acta Crystallogr., Sect. A*, 1968, **24**, 351.
27 G. M. Sheldrick, 'SHELX84 Program for Crystal Structure Solution,' personal communication.
28 G. M. Sheldrick, 'SHELX76 Program for Crystal Structure Determination and Refinement,' University of Cambridge, 1976.

Received 12*th January* 1988; *Paper* 8/00118I