Condensed heteroaromatic ring systems. Part 24.[1,2] Synthesis of rigidin, a pyrrolo[2,3-*d*]pyrimidine marine alkaloid

Takao Sakamoto,* Yoshinori Kondo, Shuichiroh Sato and Hiroshi Yamanaka

Faculty of Pharmaceutical Sciences, Tohoku University, Aobayama, Aoba-ku, Sendai 980-77, Japan

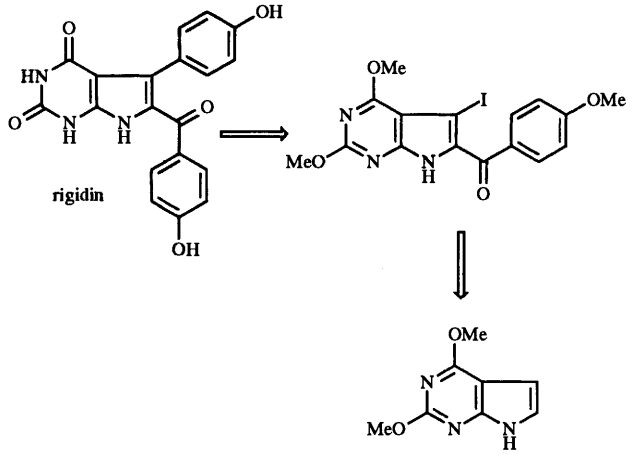
The marine alkaloid rigidin has been synthesized from 2,4-dimethoxy-7-phenylsulfonylpyrrolo[2,3-*d*]-pyrimidine. Lithiation of the pyrrolo[2,3-*d*]pyrimidine followed by electrophilic substitution with *N*,4-dimethoxy-*N*-methylbenzamide afforded a 6-(4-methoxy)benzoyl derivative which by alkaline hydrolysis and subsequent iodination was converted into 2,4-dimethoxy-5-iodopyrrolo[2,3-*d*]pyrimidin-6-yl 4-methoxyphenyl ketone. The palladium-catalysed arylation of this with 2-(4-methoxyphenyl)-1,3,2-dioxaborinane followed by demethylation with boron tribromide gave rigidin.

The pyrrolo[2,3-*d*]pyrimidine skeleton is found in a number of biologically active compounds including both antibiotics[3-5] and nucleosides.[6,7] In addition, it is contained in rigidin, a compound isolated from the Okinawan marine tunicate *Eudistoma* cf. *rigida* by Kobayashi, *et al.* in 1990 and found to inhibit calmodulin-activated brain phosphodiesterase.[8]

As an extension to our earlier report of the formation of the pyrrolopyrimidine skeleton from halogenopyrimidine derivatives by a key palladium-catalysed reaction,[9] and because of our interest in the biological activity of such compounds we report a total synthesis of rigidin.

Strategy for the synthesis of rigidin

The first total synthesis of rigidin started from 6-chlorouracil and began with pyrrole ring formation.[10] In our work, we chose 2,4-dimethoxypyrrolo[2,3-*d*]pyrimidine **1a** as starting material; this was prepared by either the palladium-catalysed reaction of 6-acetylamino-5-bromo-2,4-dimethoxypyrimidine with (*Z*)-1-ethoxy-2-(tributylstannyl)ethene as a key step[9c] or a classical pyrimidine cyclisation method.[11] Our strategy consists of the acylation by way of lithiation at the 6-position of **1a**, halogenation of the 5-position and palladium-catalysed arylation at the 5-position as shown in Scheme 1.



Scheme 1

Electrophilic substitution of pyrrolo[2,3-*d*]pyrimidines by way of lithiation

In order to effect lithiation at the 7-position of **1a** a suitable directed metallation group (DMG) was needed. Initially, Levy's method,[12] in which a *tert*-butoxycarbonyl group as a DMG was used for the lithiation of indoles at the 2-position, was applied to 7-*tert*-butoxycarbonyl-2,4-dimethoxypyrrolo[2,3-*d*]pyrimidine **1b**. In the event, reaction of **1b** with *tert*-butyllithium at −78 °C followed by quenching with deuterium oxide gave none of the expected 6-deuterio derivative, **1b** being recovered (85%). This result was interpreted as being due to lithiation difficulties associated with steric hindrance by the *tert*-butyl group, in which the *tert*-butyllithium was coordinated between N-1 of the pyrrolo[2,3-*d*]pyrimidine ring and the carbonyl group of Bu^tCO_2.

Katritzky's method[13] was then tried in which a lithiooxycarbonyl group was used as a DMG. According to this procedure, **1a** was first treated with butyllithium and then allowed to react with CO_2 to give the 7-lithiooxycarbonyl derivative. Lithiation of this with *tert*-butyllithium at −78 °C, followed by deuteriation gave a mixture of 2,4-dimethoxy[6-$^2H_1$]-pyrrolo[2,3-*d*]pyrimidine and **1a** (ratio 15:85 by ^1H NMR), in which the proportion of the former was insufficient for our purpose.

Finally, we tried Gribble's method[14] in which the phenylsulfonyl group was used as a DMG for the lithiation of indoles. 2,4-Dimethoxy-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine **1c** when treated with *tert*-butyllithium at −78 °C followed by deuterium oxide gave the 6-deuterio derivative **2a** in 83% yield. This reacted smoothly with electrophiles other than deuterium oxide to give the products listed in Table 1 in the yields shown.

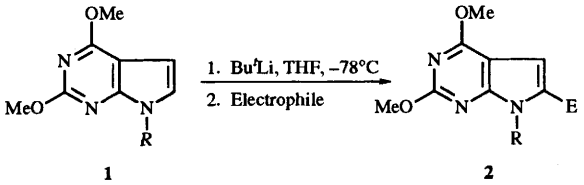
On the basis of the results described, we concluded that phenylsulfonyl group is a favourable DMG for the lithiation at the 6-position of pyrrolo[2,3-*d*]pyrimidine ring.

Halogenation of pyrrolo[2,3-*d*]pyrimidines

In order to introduce a 5-aryl group into the pyrrolo[2,3-*d*]-pyrrole skeleton halogenation of this system was initially necessary. Bromination of pyrrolo[2,3-*d*]pyrimidine **3a** and 2,4-dimethylpyrrolo[2,3-*d*]pyrimidine **4a** with bromine in *N*,*N*-dimethylformamide (DMF) at room temperature gave the corresponding 5-bromo derivatives **5a**,**b** in 40 and 74% yields, respectively. However, a similar bromination of **1a** gave a mixture of 5-bromo derivative **5c** and the 5,6-dibromo derivative even at −30 °C.

In contrast, iodination of the same substrates with iodine in the presence of potassium hydroxide in DMF gave only the 5-iodo derivatives **5d**,**e**,**f** with none of the 5,6-diiodo derivatives. In the light of these results and because iodides are more reactive than bromides in palladium-catalysed reactions, we chose the former for the introduction of an aryl group into the pyrrolo[2,3-*d*]pyrimidine skeleton.

Table 1 Electrophilic substitution by way of lithiation

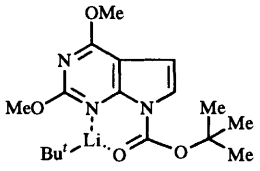


1

a R = H
b R = COO'Bu'
c R = SO_2Ph

2

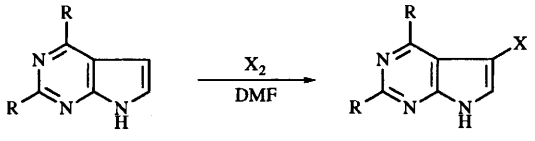
a R = SO_2Ph, E = D
b R = SO_2Ph, E = I
c R = SO_2Ph E = COOMe
d R = SO_2Ph E = CH(OH)Ph



R	Electrophile	E	Yield (%)
COO'Bu'	D_2O	D	0[a]
COOLi	D_2O	D	85[b]
SO_2Ph	D_2O	D	83[c]
SO_2Ph	I_2	I	80
SO_2Ph	CO_2	CO_2Me	40[d]
SO_2Ph	PhCHO	CH(OH)Ph	82

[a] Starting material was recovered in 85%. [b] Deuterium content was 79%. [c] Deuterium content was 100%. [d] Isolation after treatment with CH_2N_2.

Table 2 Halogenation



1a R = OMe
3a R = H
4a R = Me

5a X = Br, R = H; 5b X = Br, R = Me
5c X = Br, R = OMe; 5d X = I, R = H
5e X = I, R = Me; 5f X = I, R = OMe

X	R	Reaction temp. (°C)	Reaction time (h)	Yield (%)
Br	H	RT	2	40
Br	Me	RT	0.5	74
Br	OMe	−30	5	31[a]
I	H	RT	2	70
I	Me	RT	2	84
I	OMe	RT	2	61

[a] 5,6-Dibromo derivative was also obtained in 24%.

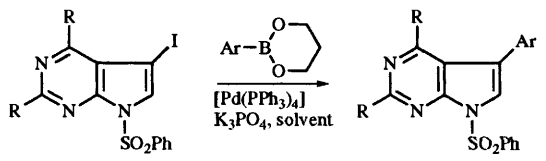
Palladium-catalysed arylation of 5-iodopyrrolo[2,3-*d*]pyrimidines

Of the methods available for the palladium-catalysed arylation of aromatic halides with metalloarenes,[15] we chose arylboronic esters as the metalloarenes for the arylation of the pyrrolo-[2,3-*d*]pyrimidine ring at the 5-position. Thus, 5-iodo-2,4-dimethoxy-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine **6b** reacted with 2-(4-methoxyphenyl)-1,3,2-dioxaborinane in the presence of tetrakis(triphenylphosphine)palladium and potassium phosphate in tetrahydrofuran (THF) under reflux to give 2,4-dimethoxy-5-(4-methoxyphenyl)-7-phenylsulfonylpyrrolo-[2,3-*d*]pyrimidine **7c** (33%) together with recovered **6b** (42%). A similar reaction in DMF at 100 °C gave **7c** (41%) and the de-phenylsulfonylated compound **8c** (14%), while the reaction in THF gave no **8c** (Table 3).

Synthesis of rigidin

The total synthesis of rigidin was performed by the route shown in Scheme 2. Thus, 2,4-dimethoxy-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine **1c** was lithiated with *tert*-butyllithium at −78 °C and then treated with 4-methoxybenzaldehyde to give 6-[hydroxy(4-methoxyphenyl)methyl]-2,4-dimethoxy-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine **9**. This was oxidized with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) to afford the 4-methoxybenzoyl derivative **10** (87%). Compound **10** was also obtained from the reaction of the lithiated **1c** with *N*,4-dimethoxy-*N*-methylbenzamide (55%). Alkaline hydrolysis of **10** and subsequent iodination gave the

Table 3 Palladium-catalysed arylation



6a R = Me
6b R = OMe

7a-c

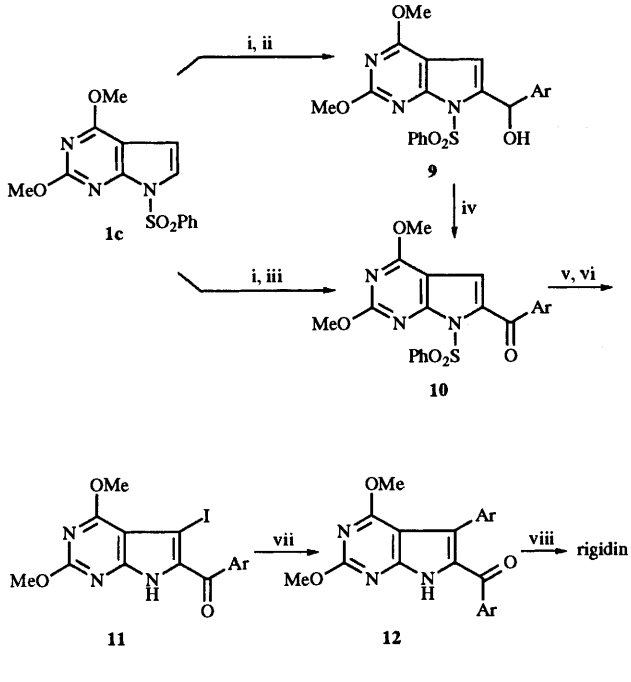
+

8a-c

a R = Me, Ar = Ph
b R = Me, Ar = 4-$MeOC_6H_4$
c R = OMe, Ar = 4-$MeOC_6H_4$

R	Ar	Solvent	Reaction temp. (°C)	Reaction time (h)	Yield (%) 7	8
OMe	4-$MeOC_6H_4$	THF	Reflux	48	33[a]	0
Me	C_6H_5	DMF	100	4	54	23
Me	4-$MeOC_6H_4$	DMF	100	4	65	Trace
OMe	4-$MeOC_6H_4$	DMF	100	4	41	14

[a] Starting material **6b** was recovered in 42%.



Scheme 2 *Reagents and conditions:* i, Bu'Li, THF, −78 °C; ii, ArCHO; iii, ArCON(Me)OMe; iv, DDQ, dioxan; v, KOH, MeOH; vi, I_2, KOH, DMF; vii, $ArBO(CH_2)_3O$, $[Pd(PPh_3)_4]$, K_3PO_4, DMF; viii, BBr_3, $(ClCH_2)_2$

5-iodo derivative **11** which was converted into the 4-methoxyphenyl derivative **12** by a palladium-catalysed reaction with 2-(4-methoxyphenyl)-1,3,2-dioxaborinane. Finally, demethylation of **12** with boron tribromide in 1,2-dichloroethane gave rigidin in 41% yield, the spectroscopic results for which were consistent with those reported.

Experimental

General comments

Tetrahydrofuran (THF) was distilled from sodium–benzophenone ketyl before use. BuLi and Bu^{t}Li were titrated using 2,5-dimethoxybenzyl alcohol[16] before use. [$Pd(PPh_3)_4$] was prepared from [$Pd(PPh_3)_2Cl_2$], PPh_3 and BuLi (1:2:2).[17] Mps and bps are uncorrected. IR spectra were taken on a JASCO IR-A1 810 spectrophotometer. ^{1}H NMR spectra were recorded on a Hitachi R-3000 (300 MHz) spectrometer. ^{13}C NMR spectra were recorded on a JEOL JNM GX-500. Chemical shifts are expressed as δ values, and coupling constants are expressed in Hz. The following abbreviations are used: s = singlet, d = doublet, t = triplet, q = quartet, quin = quintet, m = multiplet, dd = double doublet and br = broad. Mass spectra (MS) and high resolution mass spectra (HRMS) were recorded on a JMS-DX303 and JMS-AX500 instruments.

7-*tert*-Butoxycarbonyl-2,4-dimethoxypyrrolo[2,3-*d*]pyrimidine 1b

A mixture of the pyrrolo[2,3-*d*]pyrimidine **1a**[9c,11] (537 mg, 3 mmol), di-*tert*-butyl dicarbonate (785 mg, 3.6 mmol) and 4-(*N*,*N*-dimethylamino)pyridine (37 mg, 0.3 mmol) in anhydrous MeCN (5 cm^3) was stirred at room temperature for 0.5 h. After evaporation of the MeCN, 1 mol dm^{-3} aq. $KHSO_4$ (4 cm^3) was added to the mixture which was then extracted with AcOEt (3 × 30 cm^3). The combined extracts were washed with 1 mol dm^{-3} aq. $KHSO_4$ (4 cm^3), water (4 cm^3), 1 mol dm^{-3} aq. $NaHCO_3$ (4 cm^3), and saturated brine (8 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure. The residue was washed with light petroleum and recrystallized from AcOEt–hexane to give colourless needles (785 mg, 94%), mp 100–101 °C; δ_H($CDCl_3$ + TMS) 1.68 (9 H, s), 4.06 (3 H, s), 4.09 (3 H, s), 6.48 (1 H, d, *J* 4.0) and 7.35 (1 H, d, *J* 4.0); ν_{max}($CHCl_3$)/cm^{-1} 1750, 1610 and 1580; *m*/*z* 279 (M$^+$) (Found: C, 55.6; H, 5.95; N, 14.8. Calc. for $C_{13}H_{17}N_3O_4$: C, 55.91; H, 6.13; N, 15.05%).

Phenylsulfonylation of pyrrolo[2,3-*d*]pyrimidines: general procedure A

A suspension of NaH in THF [obtained from NaH (60% dispersion in mineral oil) by washing with THF] was added to a solution of a pyrrolo[2,3-*d*]pyrimidine in THF, and the mixture was stirred at room temperature for 1 h. $PhSO_2Cl$ was added to the mixture which was then stirred at room temperature for 1 h. After this it was evaporated under reduced pressure and diluted with ice–water. After neutralization with saturated aq. NH_4Cl (20 cm^3) the mixture was extracted with $CHCl_3$ (2 × 50 cm^3). The combined extracts were washed with saturated brine (10 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure to give the residue.

2,4-Dimethoxy-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine 1c

According to general procedure A, the crude product obtained from the reaction of **1a** (1.19 g, 6.65 mmol) in THF (150 cm^3), NaH (60% dispersion in mineral oil; 0.53 g, 13 mmol) in THF (10 cm^3) and $PhSO_2Cl$ (0.94 cm^3, 7.3 mmol), was purified by silica gel column chromatography using hexane–AcOEt (3:1) as eluent. Recrystallization of the crude product from AcOEt–hexane gave colourless prisms (2.01 g, 95%), mp 140–141 °C; δ_H($CDCl_3$ + TMS) 4.04 (6 H, s), 6.53 (1 H, d, *J* 4.0), 7.40 (1 H, d, *J* 4.0), 7.49–7.63 (3 H, m) and 8.16–8.19 (2 H, m); ν_{max}(KBr)/cm^{-1} 1610, 1590, 1380 and 1180; *m*/*z* 319 (M$^+$) [Found (HRMS): *m*/*z* 319.0620. Calc. for $C_{14}H_{13}N_3O_4S$: 319.0625].

Deuteriation of 2,4-dimethoxy-7-(lithiooxycarbonyl)pyrrolo-[2,3-*d*]pyrimidine

1.14 mol dm^{-3} BuLi in hexane (1.92 cm^3, 2.2 mmol) was added to a solution of **1a** (358 mg, 2 mmol) in THF (15 cm^3) at −78 °C under argon atmosphere, and the mixture was stirred at the same temperature for 1 h. The mixture was saturated with dry CO_2 at the same temperature after which it was stirred for 2 h and allowed to reach 5 °C. After evaporation of the mixture at 5 °C, THF (15 cm^3) was added to the residue followed by 1.20 mol dm^{-3} Bu^{t}Li in pentane (1.75 cm^3, 2.1 mmol), added at −78 °C. The mixture was stirred at the same temperature for 2 h after which it was treated with D_2O (0.2 cm^3) and allowed to reach room temperature. The reaction was quenched by the addition of saturated aq. NH_4Cl (10 cm^3) to the mixture which was then extracted with AcOEt (3 × 50 cm^3). The combined extracts were washed with saturated aq. NaCl (10 cm^3), dried ($MgSO_4$) and evaporated. The residue (305 mg) was analysed by ^{1}H NMR spectroscopy.

Electrophilic substitution by way of lithiation of 2,4-dimethoxy-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine: general procedure B

A pentane solution of Bu^{t}Li was added to a THF solution of **1c** at −78 °C under argon atmosphere. The mixture was stirred at −78 °C for 0.5 h after which an electrophile was added to it.

2,4-Dimethoxy-7-phenylsulfonyl[6-^{2}H$_1$]pyrrolo[2,3-*d*]pyrimidine 2a. According to general procedure B, **1c** (319 mg, 1 mmol) in THF (5 cm^3) was lithiated with 1.23 mol dm^{-3} Bu^{t}Li in pentane (0.85 cm^3, 1.05 mmol) and then treated with D_2O (0.1 cm^3) at −78 °C. The mixture was stirred at −78 °C for 2 h after which it was allowed to reach room temperature. It was then quenched with saturated aq. NH_4Cl (10 cm^3) and extracted with AcOEt (3 × 20 cm^3). The combined extracts were washed with saturated brine (5 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure. The residue was recrystallized from AcOEt–hexane to give colourless prisms (262 mg, 82%); δ_H($CDCl_3$ + TMS) 4.03 (3 H, s), 4.04 (3 H, s), 6.53 (1 H, s), 7.49–7.65 (3 H, m) and 8.16–8.20 (2 H, m); ν_{max}($CHCl_3$)/cm^{-1} 1600, 1570, 1360 and 1190; *m*/*z* 321 (M$^+$).

6-Iodo-2,4-dimethoxy-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine 2b. According to general procedure B, **1c** (319 mg, 1 mmol) in THF (5 cm^3) was lithiated with 1.24 mol dm^{-3} Bu^{t}Li in pentane (0.85 cm^3, 1.05 mmol) and then treated with I_2 (267 mg, 1.05 mmol) in THF (3 cm^3) at −78 °C for 2 h. After this the reaction mixture was quenched with saturated aq. NH_4Cl (10 cm^3) and extracted with AcOEt (3 × 30 cm^3). The combined extracts were washed with 20% aq. $Na_2S_2O_3$ (10 cm^3) and saturated brine (10 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. Purification of the residue by silica gel column chromatography using hexane–AcOEt (4:1) as an eluent gave the crude product which was recrystallized from AcOEt–hexane to afford colourless needles (360 mg, 80%), mp 176–178 °C; δ_H($CDCl_3$ + TMS) 4.02 (3 H, s), 4.07 (3 H, s), 6.90 (1 H, s), 7.49–7.63 (3 H, m) and 8.17–8.22 (2 H, m); ν_{max}($CHCl_3$)/cm^{-1} 1600, 1580, 1380 and 1190; *m*/*z* 445 (M$^+$) (Found: C, 37.8; H, 2.8; N, 9.6; I, 28.5; S, 7.5. Calc. for $C_{14}H_{12}IN_3O_4S$: C, 37.77; H, 2.72; N, 9.44; I, 28.50; S, 7.20%).

Methyl 2,4-dimethoxy-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine-6-carboxylate 2c. According to general procedure B, **1c** (319 mg, 1 mmol) in THF (5 cm^3) was lithiated with 1.16 mol dm^{-3} Bu^{t}Li in pentane (0.91 cm^3, 1.05 mmol) and then treated with dry CO_2 gas at −78 °C for 2 h. Trifluoroacetic acid (0.85 cm^3, 1.1 mmol) was added to the mixture which after being allowed to reach room temperature was treated with 0.3 mol dm^{-3} CH_2N_2 in Et_2O[18] (30 cm^3). After 24 h at room temperature the mixture was washed with saturated brine (5 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure. Purification of the residue by silica gel column chromatography using hexane–AcOEt (4:1) as eluent gave the crude product which crystallized from AcOEt as colourless prisms (206 mg,

55%), mp 150–151 °C; δ_H($CDCl_3$ + TMS) 3.95 (3 H, s), 4.07 (3 H, s), 4.11 (3 H, s), 7.07 (1 H, s), 7.56–7.69 (3 H, m) and 8.41–8.45 (2 H, m); ν_{max}($CHCl_3$)/cm^{-1} 1720, 1600, 1570, 1390 and 1190; *m/z* 377 (M^+) (Found: C, 50.8; H, 4.1; N, 11.1; S, 8.55. Calc. for $C_{16}H_{15}N_3O_6S$: C, 50.92; H, 4.01; N, 11.13; S, 8.50%).

6-[Hydroxy(phenyl)methyl]2,4-dimethoxy-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine 2d. According to general procedure B, **1c** (319 mg, 1 mmol) in THF (5 cm^3) was lithiated with 1.20 mol dm^{-3} Bu^{t}Li in pentane (0.85 cm^3, 1.05 mmol) and then treated with benzaldehyde (0.11 cm^3, 1.05 mmol) in THF (3 cm^3) at −78 °C for 2 h. The reaction mixture was quenched with saturated aq. NH_4Cl (10 cm^3) and extracted with AcOEt (3 × 30 cm^3). The combined extracts were washed with saturated brine, dried ($MgSO_4$) and concentrated under reduced pressure. Purification of the residue by silica gel column chromatography using hexane–AcOEt (4:1) as eluent gave a colourless viscous liquid (349 mg, 82%); δ_H($CDCl_3$ + TMS) 3.42 (1 H, br s), 3.98 (6 H, s), 6.18 (1 H, s), 6.45 (1 H, d, *J* 5.5), 7.35–7.59 (8 H, m) and 7.95–7.98 (2 H, m); ν_{max}($CHCl_3$)/cm^{-1} 3430, 1610, 1590, 1380 and 1180; *m/z* 425 (M^+) [Found (HRMS): *m/z* 425.1028. Calc. for $C_{21}H_{19}N_3O_5S$: 425.1044].

Bromination of pyrrolo[2,3-*d*]pyrimidines: general procedure C
Br_2 in DMF was added to a solution of the pyrrolo[2,3-*d*]-pyrimidine in DMF and stirred at the temperature and for the time shown in Table 2. The mixture was poured into ice–water, to which $Na_2S_2O_3$ was then added. After neutralization with K_2CO_3, the mixture was extracted with AcOEt (3 × 50 cm^3). The combined extracts were washed with saturated brine (20 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure. The residue was recrystallized from AcOEt.

5-Bromopyrrolo[2,3-*d*]pyrimidine 5a. According to general procedure C, the pyrrolo[2,3-*d*]pyrimidine **3a**[9c] (357 mg, 3 mmol) in DMF (10 cm^3) was treated with Br_2 (479 mg, 3 mmol) in DMF (10 cm^3) to yield colourless scales (237 mg, 40%), mp 199–201 °C; δ_H($CDCl_3$ + TMS) 7.39 (1 H, d, *J* 2.2), 8.96 (1 H, s) and 10.04–10.11 (1 H, br); ν_{max}(KBr)/cm^{-1} 3050, 2950, 2750, 1600 and 1580; *m/z* 199 (M^+) (Found: C, 36.4; H, 2.0; N, 21.1; Br, 40.4. Calc. for $C_6H_4BrN_3$: C, 36.39; H, 2.04; N, 21.22; Br, 40.35%).

5-Bromo-2,4-dimethylpyrrolo[2,3-*d*]pyrimidine 5b. According to general procedure C, the pyrrolo[2,3-*d*]pyrimidine **4a**[9c] (441 mg, 3 mmol) in DMF (10 cm^3) reacted with Br_2 (479 mg, 3 mmol) in DMF (10 cm^3) to yield colourless needles (501 mg, 74%), mp 235–237 °C; δ_H($CDCl_3$ + TMS) 2.77 (3 H, s), 2.94 (3 H, s), 7.24 (1 H, s) and 10.81–10.86 (1 H, br); ν_{max}(KBr)/cm^{-1} 3200, 3130, 2800, 1610 and 1570; *m/z* 227 (M^+) (Found: C, 42.4; H, 3.55; N, 18.5; Br, 35.3. Calc. for $C_8H_8BrN_3$: C, 42.50; H, 3.57; N, 18.59; Br, 35.34%).

Bromination of 2,4-dimethoxypyrrolo[2,3-*d*]pyrimidine
The crude product obtained from the reaction of **1a** (537 mg, 3 mmol) in DMF (10 cm^3) and Br_2 (479 mg, 3 mmol) in DMF (10 cm^3) according to general procedure C was purified by silica gel column chromatography using hexane–AcOEt (5:1) as eluent. The first eluate gave 5,6-dibromo-2,4-dimethoxypyrrolo[2,3-*d*]pyrimidine which crystallized from AcOEt as colourless needles (313 mg, 31%), mp 200–203 °C; δ_H($CDCl_3$ + TMS) 3.97 (3 H, s), 4.10 (3 H, s) and 12.01–12.04 (1 H, br); ν_{max}(KBr)/cm^{-1} 3400, 3050, 2950, 1630 and 1590; *m/z* 336 (M^+) (Found: C, 28.6; H, 2.1; N, 12.5. Calc. for $C_8H_7Br_2N_3O_2$: C, 28.52; H, 2.09; N, 12.47%).

The second eluate gave 5-bromo-2,4-dimethoxypyrrolo[2,3-*d*]pyrimidine **5c** which crystallized from AcOEt–hexane as colorless needles (186 mg, 24%), mp 210–212 °C; δ_H($CDCl_3$ + TMS) 3.99 (3 H, s), 4.11 (3 H, s), 6.93 (1 H, d, *J* 2.6) and 9.29–9.32 (1 H, br); ν_{max}(KBr)/cm^{-1} 3400, 3200, 1610 and 1580; *m/z* 257 (M^+) [Found (HRMS): 256.9840. Calc. for $C_8H_8{}^{79}BrN_3O_2$: 256.9800].

Iodination of pyrrolo[2,3-*d*]pyrimidines: general procedure D
A mixture of the pyrrolo[2,3-*d*]pyrimidine, I_2, and KOH in DMF was stirred at the temperature and for the time shown in Table 2 after which it was treated with 20% aq. $Na_2S_2O_3$ (50 cm^3), and extracted with AcOEt (3 × 50 cm^3). The combined extracts were washed with saturated brine (20 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure. The residue was recrystallized from AcOEt.

5-Iodopyrrolo[2,3-*d*]pyrimidine 5d. According to general procedure D, **3a**[9c] (357 mg, 3 mmol), I_2 (838 mg, 3.3 mmol) and KOH (168 mg, 9 mmol) in DMF (15 cm^3) reacted to give colourless needles (515 mg, 70%), mp 210–213 °C; δ_H($CDCl_3$ + TMS) 7.47 (1 H, d, *J* 2.2), 8.84 (1 H, s), 8.95 (1 H, s) and 10.22–10.31 (1 H, br); ν_{max}(KBr)/cm^{-1} 3070, 2976, 2800 and 1600; *m/z* 246 (M^+) (Found: C, 29.7; H, 1.9; N, 17.3; I, 51.7. Calc. for $C_6H_4IN_3$: C, 29.41; H, 1.65; N, 17.15; I, 51.79%).

5-Iodo-2,4-dimethylpyrrolo[2,3-*d*]pyrimidine 5e. According to general procedure D, **4a** (1.56 g, 10.6 mmol), I_2 (2.96 g, 11.7 mmol) and KOH (1.78 g, 32 mmol) in DMF (25 cm^3) reacted to give colourless needles (2.42 g, 84%), mp 197–200 °C; δ_H($CDCl_3$ + TMS) 2.78 (3 H, s), 2.98 (3 H, s), 7.36 (1 H, s) and 11.19 (1 H, br s); ν_{max}(KBr)/cm^{-1} 3200, 3130, 3000, 2800, 1600 and 1570; *m/z* 273 (M^+) (Found: C, 35.4; H, 3.0; N, 15.4; I, 46.6. Calc. for $C_8H_8IN_3$: C, 35.19; H, 2.98; N, 15.39; I, 46.47%).

5-Iodo-2,4-dimethoxypyrrolo[2,3-*d*]pyrimidine 5f. According to general procedure D, **1a** (1.07 g, 6 mmol), I_2 (1.68 g, 6.6 mmol) and KOH (1.12 g, 20 mmol) in DMF (20 cm^3) reacted to give colourless needles (1.12 g, 61%), mp 199–202 °C; δ_H($CDCl_3$ + TMS) 4.00 (3 H, s), 4.13 (3 H, s), 7.04 (1 H, d, *J* 2.6) and 9.14–9.16 (1 H, br); ν_{max}(KBr)/cm^{-1} 3100, 2950, 1620 and 1580; *m/z* 306 (M^+) (Found: C, 31.55; H, 2.7; N, 13.9. Calc. for $C_8H_8IN_3O_2$: C, 31.50; H, 2.64; N, 13.77%).

5-Iodo-2,4-dimethyl-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine 6a. According to general procedure A, purification of the residue obtained from the reaction of **5e** (1.37 g, 5 mmol) in THF (100 cm^3), NaH (60% dispersion in mineral oil; 400 mg, 10 mmol) in THF (10 cm^3) and $PhSO_2Cl$ (0.69 cm^3, 5.5 mmol) by silica gel column chromatography with hexane–AcOEt (2:1) as eluent gave the crude product which crystallized from AcOEt–hexane as colourless needles (1.51 g, 73%), mp 220–221 °C (decomp.); δ_H($CDCl_3$ + TMS) 2.75 (3 H, s), 2.88 (3 H, s), 7.50–7.67 (1 H, m), 7.77 (3 H, s) and 8.21–8.26 (2 H, m); ν_{max}(KBr)/cm^{-1} 1570, 1560, 1380 and 1180; *m/z* 413 (M^+) (Found: C, 40.6; H, 3.0; N, 10.4. Calc. for $C_{14}H_{12}N_3O_2S$: C, 40.69; H, 2.93; N, 10.17%).

5-Iodo-2,4-dimethoxy-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine 6b. According to general procedure A, purification of the residue obtained from **5f** (1.22 g, 4 mmol) in THF (100 cm^3), NaH (60% dispersion in mineral oil; 320 mg, 8 mmol) in THF (10 cm^3) and $PhSO_2Cl$ (0.55 cm^3, 4.4 mmol) by silica gel column chromatography using hexane–AcOEt (2:1) as eluent gave the crude product which crystallized from AcOEt–hexane as colourless prisms (1.61 g, 90%), mp 188 °C; δ_H($CDCl_3$ + TMS) 4.04 (3 H, s), 4.06 (3 H, s), 7.50–7.68 (4 H, m) and 8.16–8.19 (2 H, m); ν_{max}(KBr)/cm^{-1} 1600, 1580, 1360 and 1180 (Found: C, 37.9; H, 2.8; N, 9.5; S, 7.0. Calc. for $C_{14}H_{13}IN_3O_4S$: C, 37.77; H, 2.72; N, 9.44; S, 7.20%).

2(4-Methoxyphenyl)-1,3,2-dioxaborinane
A mixture of 4-methoxyphenylboronic acid[19] (1.40 g, 10.3 mmol), propane-1,3-diol (784 mg, 10.3 mmol) and $MgSO_4$ (1.50 g) in benzene (25 cm^3) was stirred at room temperature for 24 h after which it was filtered. The filtrate was concentrated under reduced pressure and the residue was distilled *in vacuo* to give a colourless liquid (1.81 g, 92%), bp 130 °C/3 mmHg; δ_H($CDCl_3$ + TMS) 2.04 (2 H, quin, *J* 5.5), 3.82 (3 H, s), 4.15 (4 H, t, *J* 5.5), 6.87 (2 H, d, *J* 8.8) and 7.70 (2 H, d, *J* 8.8); ν_{max}($CHCl_3$)/cm^{-1} 1320; *m/z* 192 (M^+) [Found (HRMS): 192.0966. Calc. for $C_{10}H_{13}BO_3$: 192.0958].

Palladium-catalysed cross-coupling of 5-iodo-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidines with 2-aryl-1,3,2-dioxaborinane: general procedure E

A mixture of a 5-iodo-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine, a 2-aryl-1,3,2-dioxaborinane, K_3PO_4 and $[Pd(PPh_3)_4]$ in anhydrous DMF was heated at 100 °C for 4–6 h under argon atmosphere after which it was diluted with water (50 cm^3) and extracted with Et_2O (3 × 50 cm^3). The ethereal extract was washed with saturated brine (10 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure.

Palladium-catalysed cross-coupling of 5-iodo-2,4-dimethyl-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine 6a with 2-phenyl-1,3,2-dioxaborinane. According to general procedure E, the crude product obtained from the reaction of **6a** (413 mg, 1 mmol), 2-phenyl-1,3,2-dioxaborinane[20] (177 mg, 1.1 mmol), K_3PO_4 (318 mg, 1.5 mmol) and $[Pd(PPh_3)_4]$ (46 mg, 0.05 mmol) in anhydrous DMF (5 cm^3) was purified by silica gel column chromatography using hexane–AcOEt (4:1) as eluent. The first eluted product was 2,4-dimethyl-5-phenyl-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine **7a** which crystallized from AcOEt–hexane as colourless prisms (196 mg, 54%), mp 166–168 °C; δ_H($CDCl_3$ + TMS) 2.39 (3 H, s), 2.78 (3 H, s), 7.37–7.66 (9 H, m) and 8.27–8.31 (2 H, m); ν_{max}($CHCl_3$)/cm^{-1} 1580, 1550, 1370 and 1170; *m/z* 363 (M^+) (Found: C, 66.1; H, 4.8; N, 11.45; S, 8.85. Calc. for $C_{20}H_{17}N_3O_2S$: C, 65.91; H, 4.98; N, 11.53; S, 8.80%).

The second eluted product was 2,4-dimethyl-5-phenylpyrrolo[2,3-*d*]pyrimidine **8a** which crystallized from AcOEt–hexane as colourless prisms (52 mg, 23%), mp 183–184 °C; δ_H($CDCl_3$ + TMS) 2.55 (3 H, s), 2.81 (3 H, s), 7.21 (1 H, d, *J* 1.8), 7.36–7.48 (6 H, m) and 10.86 (1 H, br s); ν_{max}(KBr)/cm^{-1} 3100, 2850, 1570 and 1540; *m/z* 223 (M^+) [Found (HRMS): 223.1122. Calc. for $C_{14}H_{13}N_3$: 223.1109].

Palladium-catalysed cross-coupling of 6a with 2-(4-methoxyphenyl)-1,3,2-dioxaborinane 2–9. According to general procedure E, the crude product obtained from **6a** (165 mg, 0.4 mmol), 2-(4-methoxyphenyl)-1,3,2-dioxaborinane (84 mg, 0.44 mmol), K_3PO_4 (127 mg, 0.66 mmol) and $[Pd(PPh_3)_4]$ (23 mg, 0.02 mmol) in anhydrous DMF (3 cm^3) was purified by silica gel column chromatography using hexane–AcOEt (4:1) as eluent. The first eluted product was 5-(4-methoxyphenyl)-2,4-dimethyl-7-(phenylsulfonyl)pyrrolo[2,3-*d*] pyrimidine **7b** which crystallized from AcOEt–hexane as colourless scales (102 mg, 65%), mp 148 °C; δ_H($CDCl_3$ + TMS) 2.40 (3 H, s), 2.77 (3 H, s), 3.86 (3 H, s), 6.96 (2 H, d, *J* 8.8), 7.30 (2 H, d, *J* 8.8), 7.51–7.66 (4 H, m) and 8.26–8.30 (2 H, m); ν_{max}($CHCl_3$)/cm^{-1} 1550, 1380 and 1190; *m/z* 393 (M^+) (Found: C, 64.2; H, 5.05; N, 10.65; S, 8.2. Calc. for $C_{21}H_{19}N_3O_3S$: C, 63.94; H, 5.11; N, 10.65; S, 8.13%).

The second eluated product was 5-(4-methoxyphenyl)-2,4-dimethylpyrrolo[2,3-*d*]pyrimidine **8b** which crystallized from AcOEt–hexane as colourless prisms (trace), mp 210–212 °C; δ_H($CDCl_3$ + TMS) 2.53 (3 H, s), 2.79 (3 H, s), 3.87 (3 H, s), 6.98 (2 H, d, *J* 8.8), 7.14 (1 H, d, *J* 1.5), 7.37 (2 H, d, *J* 8.8) and 10.19–10.22 (1 H, br); ν_{max}(KBr)/cm^{-1} 3100, 3000, 2850, 1570 and 1540; *m/z* 253 (M^+) [Found (HRMS): 253.1207. Calc. for $C_{15}H_{15}N_3O$: 253.1215].

Palladium-catalysed cross-coupling of 5-iodo-2,4-dimethoxy-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine 6b with 2-(4-methoxyphenyl)-1,3,2-dioxaborinane. According to general procedure E, the crude product obtained from **6b** (356 mg, 0.8 mmol), 2-(4-methoxyphenyl)-1,3,2-dioxaborinane (168 mg, 0.88 mmol), K_3PO_4 (254 mg, 1.22 mmol) and $[Pd(PPh_3)_4]$ (46 mg, 0.04 mmol) in anhydrous DMF (5 cm^3) was purified by silica gel column chromatography using hexane–AcOEt (4:1) as eluent. The first eluted product was 2,4-dimethoxy-5-(4-methoxyphenyl)-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine **7c** which crystallized from AcOEt–hexane as colourless needles (139 mg, 41%), mp 173–175 °C; δ_H($CDCl_3$ + TMS) 3.86 (3 H, s), 4.00 (3 H, s), 4.06 (3 H, s), 6.95 (2 H, d, *J* 8.8), 7.41 (1 H, s), 7.43–7.66 (5 H, m) and 8.19–8.23 (2 H, m); ν_{max}($CHCl_3$)/cm^{-1} 1600, 1570, 1370 and 1180; *m/z* 425 (M^+) (Found: C, 59.3; H, 4.6; N, 9.9. Calc. for $C_{21}H_{20}N_3O_5S$: C, 59.28; H, 4.59; N, 9.88%).

The second eluted product was 2,4-dimethoxy-5-(4-methoxyphenyl)pyrrolo[2,3-*d*]pyrimidine **8c** which crystallized from AcOEt–hexane as colourless prisms (32 mg, 14%), mp 246–250 °C (decomp.); δ_H($CDCl_3$ + TMS) 3.86 (3 H, s), 4.03 (3 H, s), 4.07 (3 H, s), 6.95 (2 H, d, *J* 9.2), 6.97 (1 H, s), 7.57 (2 H, d, *J* 9.2) and 8.81–8.84 (1 H, br); ν_{max}(KBr)/cm^{-1} 3100, 2950, 2850, 1580 and 1550; *m/z* 285 (M^+) [Found (HRMS): *m/z* 285.1116. Calc. for $C_{15}H_{15}N_3O_3$: 285.1113].

6-[Hydroxy(4-methoxyphenyl)methyl]-2,4-dimethoxy-7-phenylsulfonylpyrrolo[2,3-*d*]pyrimidine 9

According to general procedure B, **1c** (319 mg, 1 mmol) in THF (5 cm^3) was lithiated with 1.23 mol dm^{-3} Bu^{t}Li in pentane (0.85 cm^3, 1.05 mmol) and then treated with 4-methoxybenzaldehyde (0.13 cm^3, 1.05 mmol) at −78 °C for 2 h. After being quenched with saturated aq. NH_4Cl (10 cm^3), the reaction mixture was extracted with AcOEt (3 × 30 cm^3) and the combined extracts were washed with saturated brine (10 cm^3), dried ($MgSO_4$) and evaporated under reduced pressure. Purification of the residue by silica gel column chromatography using hexane–AcOEt (4:1) as eluent gave the crude product which crystallized from AcOEt–hexane as colourless prisms (360 mg, 79%), mp 146–149 °C; δ_H($CDCl_3$ + TMS) 3.41 (1 H, d, *J* 5.1), 3.85 (3 H, s), 3.98 (3 H, s), 3.99 (3 H, s), 6.19 (1 H, s), 6.42 (1 H, d, *J* 5.1), 6.92 (2 H, d, *J* 8.8), 7.36–7.61 (5 H, m) and 7.96–7.99 (2 H, m); ν_{max}($CHCl_3$)/cm^{-1} 3580, 1610, 1590, 1370 and 1160; *m/z* 455 (M^+) (Found: C, 57.75; H, 4.6; N, 9.1; S, 6.9. Calc. for $C_{22}H_{21}N_3O_6S$: C, 58.01; H, 4.65; N, 9.23; S, 7.04%).

2,4-Dimethoxypyrrolo[2,3-*d*]pyrimidin-6-yl 4-methoxyphenyl ketone 10

(1) Compound **9** (427 mg, 0.94 mmol) was added portionwise to a suspension of pyridinium chlorochromate (607 mg, 2.82 mmol) in anhydrous CH_2Cl_2 (10 cm^3) and the mixture was stirred at room temperature for 3 h. After this it was filtered and concentrated under reduced pressure. Purification of the residue by silica gel column chromatography using hexane–Et_2O (2:1) as an eluent gave the crude product which crystallized from AcOEt–hexane as colourless scales (115 mg, 27%).

(2) A mixture of **9** (114 mg, 0.25 mmol), dichlorodicyanobenzoquinone (57 mg, 0.25 mmol) in dioxane (5 cm^3) was refluxed for 15 min and then evaporated CH_2Cl_2 was added to the residue and the mixture was filtered and concentrated under reduced pressure. Purification of the residue by silica gel column chromatography using hexane–AcOEt (4:1) gave the crude product which crystallized from AcOEt as colourless scales (98 mg, 87%).

(3) According to general procedure B, **1c** (319 mg, 1 mmol) in THF (5 cm^3) was lithiated with 1.21 mol dm^{-3} Bu^{t}Li in pentane (0.87 cm^3, 1.05 mmol) and then treated with *N*,4-dimethoxy-*N*-methylbenzamide[20] (205 mg, 1.05 mmol) in THF (2 cm^3) at −78 °C for 2 h. After being quenched with saturated aq. NH_4Cl (10 cm^3), the reaction mixture was extracted with AcOEt (3 × 30 cm^3) and the combined extracts were washed with saturated brine (10 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure. Purification of the residue by silica gel column chromatography using hexane–AcOEt (4:1) as eluent gave the crude product which crystallized from AcOEt as colourless scales (252 mg, 55%), mp 199–200 °C; δ_H($CDCl_3$ + TMS) 3.91 (3 H, s), 4.06 (3 H, s), 4.15 (3 H, s), 6.78 (1 H, s), 6.99 (2 H, d, *J* 8.8), 7.58–7.70 (3 H, m), 8.02 (2 H, d, *J* 8.8) and 8.50 (2 H, m); ν_{max}($CHCl_3$)/cm^{-1} 1600, 1570, 1470, 1380 and 1160; *m/z* 453 (M^+) [Found (HRMS): 453.0990. Calc. for $C_{22}H_{19}N_3O_6S$: 453.0995].

2,4-Dimethoxypyrrolo[2,3-*d*]pyrimidin-6-yl 4-methoxyphenyl ketone

A mixture of **10** (236 mg, 0.52 mmol), 3 mol dm^{-3} KOH (3 cm^3), THF (30 cm^3) and MeOH (5 cm^3) was stirred at room temperature for 2 h after which it was evaporated and treated with saturated aq. NH_4Cl (20 cm^3). The mixture was extracted with AcOEt (3 × 30 cm^3) and the combined extracts were washed with brine (10 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure. Recrystallization of the residue from AcOEt gave colourless prisms (0.15 g, 91%), mp 217–219 °C; δ_H($CDCl_3$ + TMS) 3.91 (3 H, s), 4.05 (3 H, s), 4.08 (3 H, s), 7.01 (2 H, d, *J* 8.8), 7.09 (1 H, d, *J* 2.2), 7.97 (2 H, d, *J* 8.8) and 9.40 (1 H, br s); ν_{max}($CHCl_3$)/cm^{-1} 3400, 1600, 1570, 1490, 1470 and 1370; *m/z* 313 (M^+) (Found: C, 61.3; H, 4.9; N, 13.35. Calc. for $C_{16}H_{15}N_3O_4$: C, 61.34; H, 4.83; N, 13.41%).

5-Iodo-2,4-dimethoxypyrrolo[2,3-*d*]pyrimidine-6-yl 4-methoxyphenyl ketone 11

According to general procedure D, a mixture of 2,4-dimethoxypyrrolo[2,3-*d*]pyrimidin-6-yl 4-methoxyphenyl ketone (290 mg, 0.93 mmol), I_2 (239 mg, 0.94 mmol) and KOH (156 mg, 2.8 mmol) in DMF (4 cm^3) was stirred at room temperature for 2 h. After treatment with 20% aq. $Na_2S_2O_3$ (5 cm^3), the mixture was extracted with AcOEt (3 × 30 cm^3) and the combined extracts were washed with saturated brine (10 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure. The residue crystallized from AcOEt as colourless prisms (353 g, 86%), mp 214–216 °C (decomp.); δ_H($CDCl_3$ + TMS) 3.90 (3 H, s), 4.03 (3 H, s), 4.15 (3 H, s), 6.99 (2 H, d, *J* 8.4), 7.83 (2 H, d, *J* 8.8) and 9.34 (1 H, br s); ν_{max}($CHCl_3$)/cm^{-1} 3400, 1600 and 1570; *m/z* 439 (M^+) (Found: C, 43.6; H, 3.3; N, 9.4; I, 28.7. Calc. for $C_{16}H_{14}IN_3O_4$: C, 43.76; H, 3.21; N, 9.57; I, 28.89%).

2,4-Dimethoxy-5-(4-methoxyphenyl)pyrrolo[2,3-*d*]pyrimidine-6-yl 4-methoxyphenyl ketone 12

According to general procedure E, **11** (351 mg, 0.8 mmol), 2-(4-methoxyphenyl)-1,3,2-dioxaborinane (169 mg, 0.88 mmol), [$Pd(PPh_3)_4$] (46 mg, 0.04 mmol) and K_3PO_4 (509 mg, 2.4 mmol) in anhydrous DMF (5 cm^3) was stirred for 6 h. Purification of the residue by silica gel column chromatography using hexane–AcOEt (2:1) as eluent gave the crude product which crystallized from AcOEt as yellow prisms (201 mg, 60%), mp 165–166 °C; δ_H($CDCl_3$ + TMS) 3.74 (6 H, s), 3.99 (3 H, s), 4.06 (3 H, s), 6.56 (2 H, d, *J* 8.8), 6.64 (2 H, d, *J* 8.8), 7.11 (2 H, d, *J* 8.4), 7.43 (2 H, d, *J* 8.4) and 9.37 (1 H, br s); ν_{max}($CHCl_3$)/cm^{-1} 3400, 1600 and 1570; *m/z* 419 (M^+) (Found: C, 65.8; H, 5.1; N, 10.0. Calc. for $C_{23}H_{21}IN_3O_5$: C, 65.86; H, 5.05; N, 10.02%).

Rigidin[2,4-dioxo-5-(4-hydroxyphenyl)-1,2,3,4-tetrahydro-[2,3-*d*]pyrimdin-6-yl 4-hydroxyphenyl ketone]

BBr_3 (0.19 cm^3, 2 mmol) was added to a suspension of **12** (84 mg, 0.2 mmol) in anhydrous 1,2-dichloroethane (10 cm^3), at −30 °C. The mixture was allowed to reach room temperature and then heated under reflux for 24 h. After cooling, the mixture was diluted with water (10 cm^3), neutralized with K_2CO_3 and extracted with AcOEt (3 × 50 cm^3). The combined extracts were washed with saturated brine (10 cm^3), dried ($MgSO_4$) and concentrated under reduced pressure. Purification of the residue by silica gel column chromatography using AcOEt as eluent gave a yellow powder (30 mg, 41%), mp > 300 °C (lit.,[8,10] mp > 300 °C); δ_H([$^2H_6$]-DMSO + TMS) 6.45 (2 H, d, *J* 8.1), 6.47 (2 H, d, *J* 7.3), 6.95 (2 H, d, *J* 8.1), 7.29 (2 H, d, *J* 7.3), 9.23–9.26 (1 H, br), 9.95–9.99 (1 H, br), 10.63 (1 H, br s), 11.17–11.21 (1 H, br) and 11.74–11.78 (1 H, br); δ_C(75 MHz [$^2H_6$]-DMSO) 183.4, 158.8, 158.0, 154.6, 149.0, 130.4, 129.7, 128.9, 126.8, 126.3, 123.0, 121.0, 112.4, 111.9 and 96.4; ν_{max}(KBr)/cm^{-1} 3200, 1700 and 1610.

References

1 Part 23, T. Sakamoto, A. Yasuhara, Y. Kondo and H. Yamanaka, *Heterocycles*, 1993, **36**, 2597.
2 A part of this work was published as a communication: T. Sakamoto, Y. Kondo, S. Sato and H. Yamanaka, *Tetrahedron Lett.*, 1994, **35**, 2919.
3 K. Anzai, G. Nakamura and S. Suzuki, *J. Antibiot., Ser. A*, 1957, **10**, 201.
4 H. Nishimura, K. Katagiri, K. Sato, M. Mayama and N. Shimaoka, *J. Antibiot., Ser. A*, 1956, **9**, 60.
5 K. V. Rao and D. W. Renn, *Antimicrobial Agents Chemotherapy*, 1963, 77.
6 J. S. Pudlo, M. R. Nassiri, E. R. Kern, L. L. Wortring, J. D. Drach and L. B. Townsend, *J. Med. Chem.*, 1990, **33**, 1984.
7 (*a*) H. Kasai, K. Kuchino and S. Nishimura, *Nucleic Acids Res.*, 1975, **2**, 1931; (*b*) H. Kasai, Z. Ohashi, F. Harada, S. Nishimura, N. J. Oppenheimer, P. F. Crain, J. G. Liehr, D. L. von Minden and J. A. McCloskey, *Biochemistry*, 1975, **14**, 4198.
8 J. Kobayashi, J. Cheng, Y. Kikuchi, M. Ishibashi, S. Yamamura, Y. Ohizumi, T. Ohta and S. Nozoe, *Tetrahedron Lett.*, 1990, **31**, 4617.
9 (*a*) T. Sakamoto, Y. Kondo and H. Yamanaka, *Chem. Pharm. Bull.*, 1982, **30**, 2417; (*b*) Y. Kondo, R. Watanabe, T. Sakamoto and H. Yamanaka, *Chem. Pharm. Bull.*, 1989, **37**, 2933; (*c*) T. Sakamoto, C. Satoh, Y. Kondo and H. Yamanaka, *Chem. Pharm. Bull.*, 1993, **41**, 81.
10 E. D. Edstrom and Y. Wei, *J. Org. Chem.*, 1993, **58**, 403.
11 F. Seela and U. Liman, *Liebigs Ann. Chem.*, 1984, 273.
12 I. Hasane, E. R. Marinelli, L.-C. C. Lin, F. W. Fowler and A. B. Levy, *J. Org. Chem.*, 1981, **46**, 157.
13 A. R. Katritzky and K. Akutagawa, *Tetrahedron Lett.*, 1985, **26**, 5935.
14 M. G. Saulnier and G. W. Gribble, *J. Org. Chem.*, 1982, **47**, 757.
15 (*a*) R. J. P. Corriu and J. P. Masse, *J. Chem. Soc., Chem. Commun.*, 1972, 144; (*b*) A. Sekiya and N. Ishikawa, *J. Organomet. Chem.*, 1976, **118**, 349; (*c*) E. Negishi, A. O. King and N. Okukado, *J. Org. Chem.*, 1977, **42**, 1823; (*d*) N. Miyaura, T. Yanagi and A. Suzuki, *Synth. Commun*, 1981, **11**, 513; (*e*) M. Satoh, N. Miyaura and A. Suzuki, *Chem. Lett.*, 1989, 1405; (*f*) Y. Hosino, N. Miyaura and A. Suzuki, *Bull. Chem. Soc. Jpn.*, 1988, **61**, 3008.
16 M. R. Winkle, J. M. Lansinger and R. C. Ronald, *J. Chem. Soc., Chem. Commun.*, 1980, 87.
17 T. Sakamoto, Y. Kondo, N. Murata and H. Yamanaka, *Tetrahedron*, 1993, **43**, 9713.
18 T. H. Black, *Aldrichimica Acta*, 1983, **16**, 3.
19 G. W. Kabalka, U. Sastry, K. A. R. Sastry, F. F. Knapp, Jr. and P. C. Srivastava, *J. Organomet. Chem.*, 1983, **259**, 269.
20 M. Pailer and W. Fenzl, *Monatsh. Chem.*, 1961, **92**, 1294.

Paper 5/04778A
Received 20*th July* 1995
Accepted 20*th September* 1995