General Methods for Synthesizing 2,4-Diacylpyrroles and their Precursors Containing One or Two Masked Acyl Groups†

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A thorough study of the synthesis of 2,4-diacylpyrroles by direct acylation of pyrrole and 2- and 3-acylpyrroles is reported. Among these, Friedel–Crafts acylation of 3-acylpyrroles is the most general and advantageous method because it utilises easily accessible starting materials. In addition it is always regiospecific and readily provides 2,4-diacylpyrroles containing identical or different acyl groups in very high yields (81–100%) under mild conditions. Alternative procedures concern the synthesis of precursors of 2,4-diacylpyrroles containing one or two acyl groups masked by a 1,3-benzodithiolyl or 1,3-benzoxathiolyl group and subsequent hydrolysis with HgO–35% aq. HBF_4–Me_2SO. Overall yields are always good (52–60%). Indirect acylation constitutes a secure complement to direct acylation when it is necessary to operate in the presence of protected acyl groups.

The only procedures of general utility for synthesizing pyrrole derivatives with two acyl groups are of very recent date and exclusively involve the synthesis of 2,5-diacylpyrroles.[1,2] Even more sparse and fragmentary is literature information on the synthesis of 2,4-diacylpyrroles. It is certainly not sufficient as a guide for synthetic projects different from the pioneering ones.[3–6] In this paper, we report results of our research which have led to the development of general methods for the synthesis of 2,4-diacylpyrroles starting from acylpyrrole derivatives *via* both direct acylation and masked acylation. The examined methods involve four different approaches: (i) direct acylation of unsubstituted pyrrole, (ii) direct acylation of 2-acylpyrroles, (iii) direct acylation of 3-acylpyrroles, (iv) acylation of pyrrole derivatives mediated by 2-substituted 1,3-benzodithiolium or 1,3-benzoxathiolium salts (Scheme 1).

Results and Discussion

The most simple approach—though utilisable only for the synthesis of 2,4-diacylpyrroles containing identical acyl groups—would be the bis-acylation of unsubstituted pyrrole (Scheme 1: **1** ⟶ **4,5** ⟶ **9**; $R^1 = R^2$). The sparse literature data concerning only the formation, in low yields, of 2,4-diacetylpyrrole[4] and 2,4-bis(2,6-dichlorobenzoyl)pyrrole[3] induced us to re-examine this approach. In order to do this, we have studied the acylation of pyrrole using both an aromatic acyl chloride (benzoyl chloride) and an aliphatic acyl chloride (hexanoyl chloride) as acylating agents, in both cases utilising $AlCl_3$ as catalyst. The acylations were carried out in anhydrous dichloromethane by varying both the reaction temperatures and times and adjusting the reagent proportions in such a way as to arrive at essentially mono- (pyrrole:acyl chloride:$AlCl_3$ = 1:1.12:1.20) or di-acylated products (pyrrole:acyl chloride:$AlCl_3$ = 1:2.24:2.40). The results reported in Table 1 allow the following conclusions to be drawn: (i) as expected from well known literature data,[7] reagent:catalyst molar ratios favourable to monoacylation, give rise to 2-acylpyrroles as main products, together with minor amounts of 3-acylpyrroles and traces of 2,4-diacylpyrroles, whereas 2,5-diacylpyrroles were completely absent (entries 1,2 and 10,11); (ii) molar ratios of reagents favourable to bis-acylation give rise exclusively to 2,4-diacylpyrroles or a mixture of 2-acylpyrroles and 2,4-diacylpyrroles, whereas 3-acylpyrroles were absent (entries 3–9 and 12–16). These results show that compared with 2-acylpyrroles, the 3-acyl derivatives are most readily converted into 2,4-diacylpyrroles; (iii) the acylation carried out with aliphatic acylating agents, which are clearly more reactive than the aromatic acylating agents,[8] more readily afford the corresponding 2,4-diacylpyrroles. Nevertheless, on carrying out the reaction with the aliphatic acyl chlorides higher yields were obtained by adding the reagents to the pyrrole in two portions (entry 16); (iv) in the most favourable conditions, the bis-acylation of pyrrole gave rise to the expected 2,4-diacylpyrroles in good yield. However, its synthetic value is limited both by the obvious difficulties in optimising yields and by the fact that the 2,4-diacylpyrroles obtained contain identical acyl groups.

Another way of dealing with the problem of synthesizing 2,4-diacylpyrroles containing the same or different acyl groups is to utilise the 2-acylpyrroles as starting compounds (Scheme 1: **4** ⟶ **9**). This choice has the advantage of utilising starting compounds which are easily prepared by well known routes,[2,7,9,10] and of exploiting the electron-withdrawing effect of the acyl group present to direct entry of the second acyl group to the 4-position. Again, there is little literature information regarding these two distinct cases. The first refers to the acetylation of 2-acetylpyrrole with acetic acid catalysed by trifluoroacetic anhydride.[4] This reaction turned out to be scarcely selective, giving rise to a reaction mixture consisting of 2,4-diacetylpyrrole (46.6%) together with 2,5-diacetylpyrrole (18.7%). The second case regards acylation of 2-(trichloroacetyl)pyrrole with aliphatic acyl chlorides.[5,6] All reactions examined gave high yields of products arising from regiospecific attack at the 4-position. However, those results may be imputed to the strong electron-withdrawing effect of the trichloroacetyl group and may therefore not be generalisable. In our research the acylations of various typical 2-acylpyrroles, in which R^2 is an aromatic, aliphatic and cycloaliphatic group, were carried out in anhydrous dichloromethane, usually under reflux, with $AlCl_3$ as catalyst, apart from the case of the pivaloylation of 2-pivaloylpyrrole in which $SnCl_4$ was used. Initially, for each reaction the molar proportions 2-acylpyrrole:acyl chloride:catalyst were 1:1.12:2.40. Double the amount of catalyst with respect to the usual values for acylations was used to take into account its interaction with the pre-existing acyl group. In subsequent experiments, the reaction conditions were optimised by first increasing the amount of catalyst and then that of the acyl chloride, prolonging reaction times until no further starting

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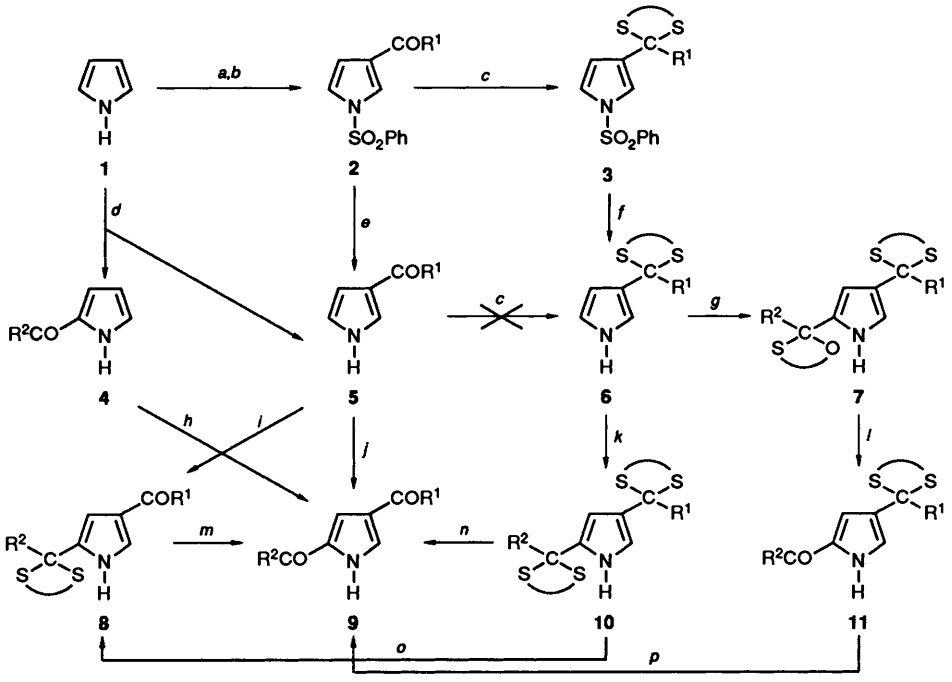
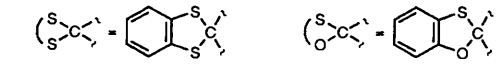


a; R^1 or/and R^2 = Ph
b; R^1 or/and R^2 = 4-MeC_6H_4
c; R^1 or/and R^2 = 4-$MeOC_6H_4$
d; R^1 or/and R^2 = 4-ClC_6H_4
e; R^1 or/and R^2 = Me
f; R^1 or/and R^2 = Bu^t
g; R^1 or/and R^2 = C_5H_{11}
h; R^1 or/and R^2 = c-C_6H_{11}
i; R^1 = Me, R^2 = Ph
j; R^1 = C_5H_{11}, R^2 = Ph
k; R^1 = C_5H_{11}, R^2 = c-C_6H_{11}
l; R^1 = c-C_6H_{11}, R^2 = 4-MeC_6H_4
m; R^1 = Ph, R^2 = C_5H_{11}
n; R^1 = 4-MeC_6H_4, R^2 = Ph
o; R^1 = 4-MeC_6H_4, R^2 = c-C_6H_{11}

Scheme 1 *Reagents and conditions: a*, $PhSO_2Cl$, 50% NaOH, Bu_4N^+ HSO_4^-, CH_2Cl_2, room temp.; *b*, R^1COCl, $AlCl_3$ ($SnCl_4$ for **2f**), dry CH_2Cl_2, room temp.; *c*, benzene-1,2-dithiol, dry benzene, HBF_4·Et_2O, reflux; *d*, (R^1 or R^2) COCl, $AlCl_3$, dry CH_2Cl_2; *e*,17% NaOH, 1,4-dioxane, room temp.; *f*, 10% KOH, 1,4-dioxane, MeOH, 50 °C to reflux; *g*, **14**, dry pyridine, dry MeCN, room temp.; *h*, R^1COCl, $AlCl_3$ ($SnCl_4$ for **9f**), reflux; *i*, **13**, dry pyridine, dry MeCN, 60 °C; *j*, R^2COCl, $AlCl_3$ ($SnCl_4$ for **9f**), dry CH_2Cl_2, room temp.; *k*, **13**, dry pyridine, dry MeCN, room temp. or 60 °C; *l*, HBF_4·Et_2O, EtOH, room temp.; *m–p*, HgO, aq. HBF_4, DMSO, room temp. to 60 °C.



2-acyl derivative remained. The results obtained here (Table 2) on the one hand constitute confirmation of the validity of the approach based on utilising 2-acylpyrroles as a starting point for obtaining 2,4-diacylpyrroles, since under the conditions adopted the reactions are regiospecific with attack of the acylating agent at the 4-position, with the exception of cases in which the electron-withdrawing effect of the pre-existing acyl group is weakened (entries 22–24 and 25–27). On the other hand, the results obtained underline the impossibility of standardising reaction conditions, precisely because of the unpredictability in balancing the various factors influencing entry of the second acyl group.

The third possibility lies in using 3-acylpyrroles as starting compounds and carrying out the acylation exploiting both the orienting effect of the pre-existing acyl group and the reactivity of the sterically less hindered α-position of pyrrole (Scheme 1: **5** ⟶ **9**). No literature information is available on this approach. This lack of information is surprising given the simplicity of this synthesis pathway. However, it should be noted that only very recently a simple and reliable method for the synthesis of 3-acylpyrroles has been reported.[9,10] Following this method, based on the formation of intermediate 3-acyl-*N*-phenylsulfonylpyrroles **2**, we first prepared a representative series of 3-acylpyrroles **5** (Scheme 1: **1** ⟶ **2** ⟶ **5**; Table 3), and subsequently carried out the acylation reaction on them. All the acylations were carried out at room temperature in anhydrous dichloromethane, using acyl chlorides as acylating agents and $AlCl_3$ as catalyst (or $SnCl_4$ for the pivaloylation of 3-pivaloylpyrrole). The molar proportions of the reagents and catalyst were maintained constant (3-acylpyrrole:acyl chloride:$AlCl_3$ = 1.00:1.12:2.40) and also the reaction time (30 min). The results are reported in Table 4. The reactions are always regiospecific and easily provide excellent yields of 2,4-diacylpyrroles **9**. Evidently, this synthetic strategy, utilisable for preparing 2,4-diacylpyrroles with the same or different acyl groups in simple standardised conditions, is certainly more valid than the previous one utilising 2-acylpyrroles, and appears to be the best available one. Application of the procedure has, moreover, provided some interesting explanations of anomalous results obtained by others as regards the overall conversion yields of pyrrole into 3-acylpyrroles. Hence whereas Kakushima *et al.*[9] reported very good conversion yields, only mediocre yields were reported by Anderson *et al.*[10] for the same sequences. We have demonstrated that these anomalies may be imputed to the fact that the deprotection of the pyrrolic nitrogen realised in the conditions described by Anderson, *i.e.* KOH–aq. MeOH, leads to substantial amounts of 3-acyl-*N*-methylpyrroles, as well as the expected 3-acylpyrroles (see Experimental section). In collateral tests, by reaction of 3-(4-chlorobenzoyl)-*N*-phenylsulfonylpyrrole **2d** with sodium methoxide in anhydrous 1,4-dioxane, we obtained 3-(4-chlorobenzoyl)-*N*-methylpyrrole in up to 78% yield together with 3-(4-chlorobenzoyl)pyrrole **5d** in only 13% yield. The interest in this experimental observation lies in its possible synthetic implications, as well as in its mechanistic ones.

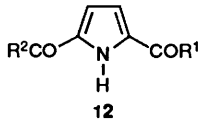
To complete our general project we have undertaken the syn-

Table 1 Acylation of pyrrole **1**

Entry	$R^1 = R^2$	Molar proportions 1:RCOCl:$AlCl_3$	Time (*t*/h)	Temp.[a]	Products/yields[b,c] (%) 4a, g	5a, g	9a, g
1	Ph	1:1.12:1.20	0.5	rt	51	8	tr
2			24	rt	47	7	tr
3		1:2.24:2.40	0.5	rt	50	tr	10
4			24	rt	47		13
5			24	r	15		55
6			72	r	4		65
7		1:1.12:1.20	0.5	rt			
		+1.12:1.20	24	rt	47		15
8			0.5	rt			
			24	r	19		50
9			0.5	rt			
			72	r	4		65
10	C_5H_{11}	1:1.12:1.20	0.5	rt	52	11	tr
11			24	rt	51	10	tr
12		1:2.24:2.40	0.5	rt	17		26
13			24	rt			39
14			0.5	rt			
			7	r			45
15		1:1.12:1.20	0.5	rt			
		+1.12:1.20	24	rt	8		60
16			0.5	rt			
			7	r			68

[a] rt = room temperature; r = reflux. [b] Yields of pure products isolated by chromatography on a silica gel column with light petroleum–diethyl ether (2:3) as eluent. [c] tr = traces. Determined by TLC and MS analyses.

thesis of 2,4-diacylpyrroles mediated by the preliminary preparation of their precursors containing one or both of the acyl groups masked by a 1,3-benzodithiolyl group (Scheme 1: **8**, **10** and **11**) followed by their hydrolysis.



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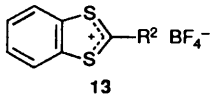
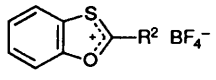
a; $R^1 = R^2 = 4\text{-}MeC_6H_4$
b; $R^1 = R^2 = 4\text{-}MeOC_6H_4$



13

a; R^2 = Ph
b; $R^2 = 4\text{-}MeC_6H_4$
c; $R^2 = 4\text{-}MeOC_6H_4$
d; $R^2 = 4\text{-}ClC_6H_4$



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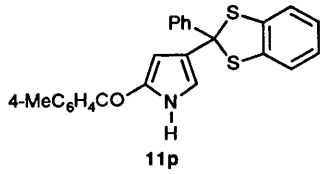
e; R^2 = Me
f; $R^2 = Bu^t$
g; $R^2 = C_5H_{11}$
h; $R^2 = c\text{-}C_6H_{11}$

The 2,4-diacylpyrroles containing a protected acyl group in the 2-position, compounds **8**, were obtained by reaction of 3-acylpyrroles **5** with the appropriate 2-substituted 1,3-benzodithiolium tetrafluoroborates **13** (Scheme 1: **5** ⟶ **8**) in acetonitrile in the presence of pyridine at 60 °C following a general procedure described previously.[2] Reaction conditions, yields and physical properties of compounds **8** are detailed in Table 5; yields range from good to excellent. It is interesting to note that, as demonstrated by some sample reactions, it is possible to obtain the same compounds **8** starting from 2,4-diacylpyrroles having both acyl groups protected (species **10**), by selective hydrolysis of the dithioketal group at the 4-position. The hydrolysis was achieved by halving the amounts of the reagent [mercury(II) oxide and aq. tetrafluoroboric acid] with respect to that required to hydrolyse both groups and by working under mild conditions. Thus, compounds **10a**, **10f** and **10h**, were converted into compounds **8a**, **8f**, **8h**, in yields of 86, 96 and 91%, respectively.

The 2,4-diacylpyrroles containing a protected acyl group in the 4-position, species **11**, were obtained indirectly *via* the intermediates **3**, **6** and **7**, by treatment of substrates **2** with benzene-1,2-dithiol, followed by deprotection of pyrrole nitrogen in basic medium, further reaction of derivatives **6** with 1,3-benzoxathiolium salts **14** and final selective acid hydrolysis of the thioketal group at the 2-position. As regards the intermediates **6**, note that pathway **2** ⟶ **3** ⟶ **6** is not an alternative to the hypothetical pathway **2** ⟶ **5** ⟶ **6**, because the latter fails in practice in the second step, giving rise to large amounts of polymeric material. The overall procedure is only apparently complicated: it makes use of well tested, simple steps (see Experimental section). However, other synthetic pathways tested were inadequate in some detail or another. For example, attempts to obtain the derivatives **11** by Friedel–Crafts reactions carried out on derivative **6a** with benzoyl chloride or 4-toluoyl chloride gave rise to 3-benzoylpyrrole **5a** in yields comparable to those of the expected products **11a** and **11p** because of an unexpected deprotection of the carbonyl group at the 3-position. Finally, the results of the attempted preparation of derivatives **11** by reaction of 2-acylpyrroles with 2-substituted 1,3-benzodithiolium salts **13** were also unsatisfactory. Reaction of 2-benzoylpyrrole **4a** with 2-phenyl-1,3-benzodithiolium tetrafluoroborate **13a** turned out



11p

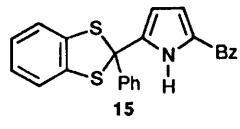


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Table 2 Acylation of 2-acylpyrroles **4**

Entry	R^1	R^2	Molar proportions 4:RCOCl:$AlCl_3$	Temp.[a]	Time (*t*/h)	Products/yields[b] (%) 4	9	12
17	Ph	Ph	1:1.12:2.40	rt	24	88	7	
18				r	8	48	27	
19				r	48	27	52	
20			1:1.12:4.20	r	8		73	
21			1:2.80:4.20	r	7		78	
22	4-MeC_6H_4	4-MeC_6H_4	1:1.12:2.40	r	24	27	61	tr
23			1:1.12:3.00	r	16		72	6[c]
24			1:1.68:3.00	r	15		93	3[c]
25	4-$MeOC_6H_4$	4-$MeOC_6H_4$	1:1.12:2.40	r	24	18	62	16[d]
26			1:1.12:3.00	r	5		60	24[d]
27			1:1.68:3.00	r	5		68	32[d]
28	4-ClC_6H_4	4-ClC_6H_4	1:1.12:2.40	r	24	34	51	
29			1:1.12:6.00	r	23		76	
30			1:4.48:6.00	r	15		89	
31	Me	Me	1:1.12:2.40	rt	7		82[e]	
32				r	3		82[e]	
33	Bu^t	Bu^t	1:1.12:2.40[f]	rt	7		88	
34				r	1		91	
35			1:2.80:6.00[f]	rt	0.5		87	
36	C_5H_{11}	C_5H_{11}	1:1.12:2.40	rt	48	10	87	
37				r	9		94	
38	c-C_6H_{11}	c-C_6H_{11}	1:1.12:2.40	r	24	80	13	
39			1:1.12:24.00	r	45	60	14	
40			1:10.08:12.00	r	21		63	
41	C_5H_{11}	Ph	1:1.12:2.40	r	9		85	
42	Ph	C_5H_{11}	1:1.12:2.40	r	24	39	46	
43			1:1.12:4.20	r	8		72	
44			1:2.80:4.20	r	8		83	

[a] rt = room temperature; r = reflux. [b] Yields of pure products separated by chromatography on a silica gel column, with light petroleum–diethyl ether (2:3) as eluent. Physical data of 2,4-diacylpyrroles **9** are identical with those reported in Table 4. [c] **12a**: m.p. 190–191 °C (from EtOH) (lit.,[2] 190–191 °C). [d] **12b**: m.p. 189–190 °C (from $CHCl_3$–MeOH) (lit.,[1] 189–190 °C). [e] The reaction mixture was poured into saturated aq. NaCl and compound **9e** was repeatedly extracted with hot $CHCl_3$. [f] Lewis acid was $SnCl_4$.

Table 3 3-Acyl-1-phenylsulfonylpyrroles **2a–h** and 3-acylpyrroles **5a–h**

Compd. 2	Yield[a] (%)	M.p.[b] (°C)	Lit. data or formula[c]	M^+ (*m*/*z*)[d]	IR (CCl_4) ν_{max}/cm^{-1}	Compd. 5	Yield[e] (%)	M.p.[f,g] (°C)	Lit. data or formula
2a	100	78	69–72[9,h]		*i*	**5a**	95	99	98.5–99[10]
2b	100	80–81	$C_{18}H_{15}NO_3S$	325	1650	**5b**	100	130	128–129[10]
2c	90	100–101	$C_{18}H_{15}NO_4S$	341	1655	**5c**	97	110	105–106.5[10]
2d	100	103–104	$C_{17}H_{12}ClNO_3S$	346	1660	**5d**	100	120	119–120[10]
2e	92	99	97–99[9,h]		*i*	**5e**	100[j]	115	114–115[k]
2f	82	85–86	$C_{15}H_{17}NO_3S$	291	1655	**5f**	95	98–99	98–100[l]
2g	97	99	$C_{16}H_{19}NO_3S$	305	1685	**5g**	100	50	49–50[6]
2h	87	106	$C_{17}H_{19}NO_3S$	317	1680	**5h**	97	29–30	$C_{11}H_{15}NO$[m]

[a] Yields of products purified by rapid chromatography on a small silica gel column by using light petroleum–diethyl ether (2:3) as eluent. [b] Crystallisation solvent was $CHCl_3$–light petroleum. [c] Satisfactory microanalyses were obtained: C ± 0.13; H ± 0.12; N ± 0.11; S ± 0.11%. [d] Mass spectra were recorded at 70 eV with an HP 5970 B mass-selective detector connected to an HP 5890 GC (cross-linked, methyl silicone capillary column). [e] Yields of products purified by rapid filtration through a small layer of silica gel by using $CHCl_3$ as eluent. [f] Crystallisation solvent was $CHCl_3$–light petroleum for compounds **5a–d, f, g**, $CHCl_3$ for **5e**, pentane for **5h**. [g] IR data are identical with those reported. [h] Ref. 11: **2a**, m.p. 59–60 °C; **2e**, m.p. 100–101 °C. [i] Identical with that reported in Ref. 11. [j] The reaction mixture was directly dried on Na_2SO_4 and evaporated under reduced pressure. The crude product was then purified by rapid chromatography on a short silica gel column, with $CHCl_3$ as eluent. [k] Ref. 12. [l] Ref. 13. [m] (Found: C, 74.6; H, 8.60; N, 8.0. $C_{11}H_{15}NO$ requires C, 74.54; H, 8.53; N, 7.90%); $\nu_{max}(CCl_4)$/cm^{-1} 1655 (CO); $\delta_H(CD_3COCD_3)$ 1.05–2.00 and 2.87–3.12 (11 H, 2 m, 1:10, c-C_6H_{11}), 6.59 (1 H, dd, $J_{1,4}$ 2.59, $J_{2,4}$ 1.50, $J_{4,5}$ 2.61, 4-H), 6.86 (1 H, dd, $J_{1,5} = J_{2,5}$ = 2.25, $J_{4,5}$ 2.61, 5-H), 7.57 (1 H, 5 lines, $J_{1,2}$ 2.78, $J_{2,4}$ 1.50, $J_{2,5}$ 2.25, 2-H) and 10.55 (1 H, m, NH); $\delta_C(CDCl_3)$ 25.47 and 29.50 (t, *J* 125, CH_2), 47.15 (d, $J_{C,H}$ 120, CH), 108.19 (d, $J_{C,H}$ 175, C-4), 119.78 (d, $J_{C,H}$ 180, C-5), 123.81 (d, $J_{C,H}$ 185, C-2) 124.13 (s, C-3) and 201.02 (s, CO); *M*, 177.

to be not very selective. Along with the desired derivative **11a**, it also gave 2-benzoyl-5-(2-phenyl-1,3-benzodithio-2-yl)pyrrole **15** derived from attack of the protected acylating agent at the 5-position. Yields and physical properties of compounds **3**, **6**, **7** and **11** are listed in Tables 6–8.

The 2,4-diacylpyrroles containing both protected acyl groups, species **10**, were obtained in excellent yields *via* reaction of the derivatives **6** with 2-substituted 1,3-benzodithiolium tetrafluoroborates **13** under the usual conditions. Yields and physical properties of the products are shown in Table 9.

Finally, 2,4-diacylpyrroles containing one or both protected groups were converted in very high, often quantitative, yields into the corresponding 2,4-diacylpyrroles **9** (Scheme 1: **8**,**11**,**10** ⟶ **9**; Tables 5, 8 and 9) by hydrolysis using mercury(II) oxide–

Table 4 2,4-Diacylpyrroles **9a–j, l, m** by acylation of 3-acylpyrroles **5a–h** and physical properties of 2,4-diacylpyrroles **9k, n, o**

Compd. 9	Chromatographic solvent[a]	Yield[b] (%)	M.p.[c] (°C)	Lit. data or formula[d]	M^+ (m/z)[e]	IR (CCl_4) ν_{max}/cm^{-1}
9a	LP–EE(2:3)	100	140	$C_{18}H_{13}NO_2$	275	1635, 1650
9b	C	95	149	$C_{20}H_{17}NO_2$	303	1605, 1630
9c	LP EE(2:3)	96	168	$C_{20}H_{17}NO_4$	335	1605, 1630
9d	C	96	174	$C_{18}H_{11}Cl_2NO_2$	343	1635, 1645
9e	LP–EE(1:9)	92[f]	136–137	139.5–140[4]		1660, 1670
9f	LP–EE(2:3)	81	140–141	$C_{14}H_{21}NO_2$	235	1645, 1660
9g	LP–EE(2:3)	100	76	$C_{16}H_{25}NO_2$	263	1650, 1710
9h	LP–EE(2:3)	91[g]	176	$C_{18}H_{25}NO_2$	287	1650, 1660
9i	C	90	103–104	$C_{13}H_{11}NO_2$	213	1630, 1670
9j	LP EE(2:3)	100	99–100	$C_{17}H_{19}NO_2$	269	1630, 1665
9l	C	93[g]	207–208	$C_{19}H_{21}NO_2$	295	1630, 1665
9m	LP–EE(2:3)	98	110	$C_{17}H_{19}NO_2$	269	1645, 1660
9k			111–112	$C_{17}H_{25}NO_2$	275	1640, 1660, 1680
9n			135–137	$C_{19}H_{15}NO_2$	289	1635, 1640
9o			199–200	$C_{19}H_{21}NO_2$	295	1640, 1650

[a] LP = light petroleum; EE = diethyl ether; C = $CHCl_3$. [b] Yields of pure isolated products. [c] Crystallised from $CHCl_3$–light petroleum. [d] Satisfactory microanalyses were obtained: C ± 0.14; H ± 0.13; N ± 0.11%. [e] For mass spectrum of **9f–l**, see footnote *d* of Table 3. [f] The reaction mixture was poured into saturated aq. NaCl and compound **9e** was repeatedly extracted with hot $CHCl_3$. [g] The following molar proportions of reagents were used: 3-acylpyrrole:cyclohexanecarbonyl chloride:$AlCl_3$ = 1:1.40:3.00.

Table 5 4-Acyl-2-(2-substituted 1,3-benzodithiol-2-yl)pyrroles **8a–h, k, n** and their hydrolysis to 2,4-diacylpyrroles **9a–h, k, n**

Compd 8	Reagent molar ratio 5:13	Time (t/h) at 60 °C	Yield[a] (%)	M.p. (°C) (solvent)[b]	Formula[c]	M^+ (m/z)	IR (CCl_4) ν_{max}/cm^{-1}	Compd. 9	Time (t/h) at 60 °C	Yield[d] (%)
8a	1:1.75	5	86	213(C–E)	$C_{24}H_{17}NOS_2$	399	1635	**9a**	2	100
8b	1:2.25	8	78	178–179(C–E)	$C_{26}H_{21}NOS_2$	427	1635	**9b**	1.5	100
8c	1:2.50	13	73	206–208(C–LP)	$C_{26}H_{21}NO_3S_2$	459	1630	**9c**	1.5	100
8d	1:3.50	10	86	208(C–E)	$C_{24}H_{15}Cl_2NOS_2$	467	1635	**9d**	1.5	98
8e	1:2.50	2	97[e]	174(C–LP)	$C_{14}H_{13}NOS_2$	275	1655	**9e**	0.5[f]	100
8f	1:4.00	7	94	258(C–LP)	$C_{20}H_{25}NOS_2$	359	1640	**9f**	8[g]	90
8g	1:3.50	7	76	95(C–LP)	$C_{22}H_{29}NOS_2$	387	1655	**9g**	0.75	91
8h	1:2.75	2	73[h]	240(C–E)	$C_{24}H_{29}NOS_2$	411	1650	**9h**	2	93
8k	1:2.50	7	81[i]	199(C–LP)	$C_{23}H_{29}NOS_2$	399	1670	**9k**	5	91
8n	1:1.25	4	87	195(B–LP)	$C_{25}H_{19}NOS_2$	413	1645	**9n**	1.5	100

[a] Yields of pure products. Chromatographic solvent was $CHCl_3$. [b] C = $CHCl_3$; E = EtOH; LP = light petroleum; B = benzene. [c] Satisfactory microanalyses were obtained: C ± 0.09; H ± 0.09; N ± 0.07; S ± 0.10%. [d] Yields of ketones purified by rapid chromatography on a silica gel column with $CHCl_3$ as eluent. Physical and spectroscopic data were identical with those of the compounds reported in Table 4. [e] 2-[(1,3-Benzodithiol-2-yl)methylene]-2-methyl-1,3-benzodithiole was also isolated in 46% yield (calculated with regard to the amount of salt **13e** used). It resulted from dimerisation of 2-methylene-1,3-benzodithiole, as previously demonstrated, and had m.p. 86–87 °C (from EtOH) (Ref. 14: m.p. 86–87 °C). [f] At room temp. [g] **8f** (5 mmol), HgO (3.25 g, 15 mmol) and 35% aq. HBF_4 (7.5 cm^3) were used. [h] 2-Cyclohexylidene-1,3-benzodithiole was also isolated in 59% yield (calculated with regard to the amount of **13h** used). It had m.p. 98–99 °C (from EtOH) (lit.,[14] 98–99 °C). Chromatographic solvent was light petroleum–diethyl ether (3:2). [i] 2-Cyclohexylidene-1,3-benzodithiole was also isolated in 81% yield. For m.p., see footnote *h*.

Table 6 1-Phenylsulfonyl-3-(2-substituted 1,3-benzodithiol-2-yl)pyrroles **3a–h** and 3-(2-substituted 1,3-benzodithiol-2-yl)pyrroles **6a–h**

Compd. 3	Yield[a,b] (%)	M.p. (°C) (solvent)[c]	Formula[d]	M^+ (m/z)	Compd. 6	Yield[e] (%)	M.p. (°C) (solvent)[c]	Formula[f]	M^+ (m/z)
3a	96	171(C)	$C_{23}H_{17}NO_2S_3$	435	**6a**	100	112(CT–LP)	$C_{17}H_{13}NS_2$	295
3b	96	161(C)	$C_{24}H_{19}NO_2S_3$	449	**6b**	100	113–114(C–LP)	$C_{18}H_{15}NS_2$	309
3c	97	175–176(C–LP)	$C_{24}H_{19}NO_3S_3$	465	**6c**	93	119–120(C–LP)	$C_{18}H_{15}NOS_2$	325
3d	100	141–142(C–LP)	$C_{23}H_{16}ClNO_2S_3$	469	**6d**	100	193(C–LP)	$C_{17}H_{12}ClNS_2$	329
3e	100	145(C–E)	$C_{18}H_{15}NO_2S_3$	373	**6e**	90	95(E)	$C_{12}H_{11}NS_2$	233
3f	97	143–144(C–LP)	$C_{21}H_{21}NO_2S_3$	415	**6f**	97	108–109(B–LP)	$C_{15}H_{17}NS_2$	275
3g	98	86(C–E)	$C_{22}H_{23}NO_2S_3$	429	**6g**	95	21(P)	$C_{16}H_{19}NS_2$	289
3h	100	120–121(C–LP)	$C_{23}H_{23}NO_2S_3$	441	**6h**	100	184(C–LP)	$C_{17}H_{19}NS_2$	301

[a] Yields of pure products: **3a–d, h** were gathered by filtration, **3e–g** were extracted with $CHCl_3$ and then purified by chromatography on a silica gel column by using light petroleum–diethyl ether (4:1) as eluent. [b] Reaction times at 50 °C were 5–6 h for **3a–d** and 3–4 h for **3e–h**. [c] C = $CHCl_3$; LP = light petroleum; E = EtOH; CT = CCl_4; B = benzene; P = pentane. [d] Satisfactory microanalyses were obtained: C ± 0.09; H ± 0.09; N ± 0.10; S ± 0.10%. [e] Yields of pure products. Hydrolyses were carried out at 50 °C for 15 min (**6a, b, d**) and for 2 h (**6e**), at 90 °C for 5 h (**6h**) and at reflux for 15 min (**6c, g**) and for 2.5 h (**6f**). [f] Satisfactory microanalyses were obtained: C ± 0.09; H ± 0.07; N ± 0.08; S ± 0.09%.

35% aq. tetrafluoroboric acid–dimethyl sulfoxide (DMSO) under conditions similar to those described previously.[2] Note that, in every case examined, the deprotection of an acyl group at the β-position occurred more easily than that at the α-position.

Conclusions.—A thorough study has been made of the synthesis of 2,4-diacylpyrroles containing different or identical acyl groups. In particular, many acylation reactions of pyrrole, 2-acylpyrroles and 3-acylpyrroles have been examined. It has

Table 7 4-(2-Substituted 1,3-benzodithiol-2-yl)-2-(2-substituted 1,3-benzoxathiol-2-yl)pyrroles **7a–h, l, o**

Compd. 7	Reagent molar ratio 6:14	Time (*t*/h) at rt[a]	Chromatographic solvent[b]	Yield[c] (%)	M.p. (°C) (solvent)[b]	Formula[d]	M^+ (*m*/*z*)
7a	1:1.25	0.5	LP–B(3:2)	97	103(A)	$C_{30}H_{21}NOS_3$	507
7b	1:1.25	0.5	*e*	97	164–165(CT)	$C_{32}H_{25}NOS_3$	535
7c	1:1.25	0.5	*e*	97	143–144(CT–LP)	$C_{32}H_{25}NO_3S_3$	567
7d	1:1.25	0.5	*e*	96	179–180(CT–LP)	$C_{30}H_{19}Cl_2NOS_3$	575
7e	1:2.25	2	LP–EE(4:1)	73[f]	122(CT–LP)	$C_{20}H_{17}NOS_3$	383
7f	1:1.50	1.5	LP–B(3:2)	86	203–204(CT–LP)	$C_{26}H_{29}NOS_3$	467
7g	1:2.25	2.5	LP–EE(4:1)	72[f]	74–75(P)	$C_{28}H_{33}NOS_3$	495
7h	1:2.25	2	LP–EE(4:1)	90	162–163(CT–LP)	$C_{30}H_{33}NOS_3$	519
7l	1:1.75	3	LP–B(3:2)	100[f]	84–85(P)	$C_{31}H_{29}NOS_3$	527
7o	1:2.00	4	LP–A(9:1)	90	95–96(P)	$C_{31}H_{29}NOS_3$	527

[a] rt = room temperature. [b] LP = light petroleum; B = benzene; EE = diethyl ether; A = acetone; CT = CCl_4; P = pentane. [c] Yields of pure isolated products. [d] Satisfactory microanalyses were obtained: C ± 0.08; H ± 0.09; N ± 0.07; S ± 0.10%. [e] The whole product was gathered by filtration. [f] Extracted from the reaction mixture with diethyl ether (3 × 100 cm^3) and then purified by chromatography on a silica gel column.

Table 8 2-Acyl-4-(2-substituted 1,3-benzodithiol-2-yl)pyrroles **11a–h, l, o** and their hydrolysis to 2,4-diacylpyrroles **9a–h, l, o**

Compd. 11	Yield[a] (%)	Time (*t*/h) at rt[b]	M.p. (°C) (solvent)[c]	Formula[d]	M^+ (*m*/*z*)	IR (CCl_4) ν_{max}/cm^{-1}	Compd. 9	Time (*t*/h) at rt[b]	Yield[e] (%)
11a	100	1	153–154(CT–LP)	$C_{24}H_{17}NOS_2$	399	1635	**9a**	0.5	94
11b	100	1	212–213(C–LP)	$C_{26}H_{21}NOS_2$	427	1620	**9b**	0.5	95
11c	100	1.5	216–217(C–LP)	$C_{26}H_{21}NO_3S_2$	459	1610	**9c**	0.3	90
11d	100	3	238(C–LP)	$C_{24}H_{15}Cl_2NOS_2$	467	1620	**9d**	1.5	100
11e	100	1	133–134(CT–LP)	$C_{14}H_{13}NOS_2$	275	1650, 1660	**9e**	0.5	91
11f	92	2[f]	103–104(P)	$C_{20}H_{25}NOS_2$	359	1630	**9f**	4	94
11g	100	1.5	90(P)	$C_{22}H_{29}NOS_2$	387	1640, 1650	**9g**	0.3	94
11h	100	1.5	198–199(C–LP)	$C_{24}H_{29}NOS_2$	411	1640	**9h**	2	97
11l	100	1	212–213(CT–LP)	$C_{25}H_{25}NOS_2$	419	1635, 1640	**9l**	0.5	91
11o	95	1	221–222(C–LP)	$C_{25}H_{25}NOS_2$	419	1640, 1645	**9o**	0.5	95

[a] Yields of pure isolated products. [b] rt = room temperature. [c] CT = CCl_4; LP = light petroleum; C = $CHCl_3$; P = pentane. [d] Satisfactory microanalyses were obtained: C ± 0.09; H ± 0.08; N ± 0.09; S ± 0.08%. [e] Yields of ketones purified by rapid chromatography on a silica gel column with $CHCl_3$ as eluent. Physical and spectroscopic data were identical with those of the compounds reported in Table 4. [f] For **11f** (5 mmol), HBF_4 (125 mmol) was used and the reaction was carried out at 60 °C.

Table 9 2,4-Bis(2-substituted 1,3-benzodithiol-2-yl)pyrroles **10a–i** and their hydrolysis to 2,4-diacylpyrroles **9a–i**

Compd. 10	Reagent ratio 6:13	Time (*t*/min) (*T*/°C)[a]	Yield[b] (%)	M.p. (°C) (solvent)[c]	Formula[d]	M^+ (*m*/*z*)	Compd. 9	Time (*t*/h) at 60 °C	Yield[e] (%)
10a	1:1.25	10(rt)	100	156(C–LP)	$C_{30}H_{21}NS_4$	523	**9a**	2	94
10b	1:1.25	20(60)	100	212(C)	$C_{32}H_{25}NS_4$	551	**9b**	2	98
10c	1:1.25	45(rt)	100	184–185(C–LP)	$C_{32}H_{25}NO_2S_4$	583	**9c**	2	98
10d	1:1.25	15(60)	100	222(C)	$C_{30}H_{19}Cl_2NS_4$	591	**9d**	3	90
10e	1:1.87	90(60)	95[f,g]	150–151(C–LP)	$C_{20}H_{17}NS_4$	399	**9e**	2[h]	77
10f	1:1.25	90(rt)	98	228(C)	$C_{26}H_{29}NS_4$	483	**9f**	8[i]	95
10g	1:1.25	30(rt)	84[f]	85(C–E)	$C_{28}H_{33}NS_4$	511	**9g**	0.75	79
10h	1:1.87	150(60)	93[f,j]	185(C–LP)	$C_{30}H_{33}NS_4$	535	**9h**	5	90
10i	1:1.25	5(rt)	100	146(C–LP)	$C_{25}H_{19}NS_4$	461	**9i**	2	100

[a] rt = room temperature. [b] Yields of pure isolated products. [c] C = $CHCl_3$; LP = light petroleum; E = EtOH. [d] Satisfactory microanalyses were obtained: C ± 0.11; H ± 0.09; N ± 0.10; S ± 0.09%. [e] Yields of ketones purified by rapid chromatography on silica gel column with $CHCl_3$ as eluent. Physical and spectroscopic data were identical with those of the compounds reported in Table 4. [f] Extracted from the reaction mixture with $CHCl_3$ and purified by chromatography on a silica gel column by using light petroleum–acetone (9:1) as eluent for **10e** and light petroleum–diethyl ether (2:3) for **10g, h**. [g] 2-[(1,3-Benzodithiol-2-yl)methylene]-2-methyl-1,3-benzodithiole was also isolated in 45% yield (calculated with regard to the amount of the salt **13e** used): m.p. 86–87 °C (from EtOH) (lit.,[14] 86–87 °C). [h] At room temp. [i] For **10f** (5 mmol), HgO (6.51 g, 30 mmol) and 35% aq. HBF_4 (15 cm^3) were used and hydrolysis was carried out at 100 °C. [j] 2-Cyclohexylidene-1,3-benzodithiole was also isolated in 52% yield (calculated with regard to the amount of the salt **13h** used): m.p. 98–99 °C (from EtOH) (lit.,[14] 98–99 °C).

been established that the bis-acylation of pyrrole can lead to 2,4-diacylpyrroles in good yields. Nevertheless, this simple approach, apart from suffering from the limitation of being applicable only to the synthesis of 2,4-diacylpyrroles containing identical acyl groups, also suffers from having to use non-standard reaction conditions. It has also been established that 2,4-diacylpyrroles with either identical or different acyl groups may conveniently be obtained *via* acylation of either 2-acylpyrroles or 3-acylpyrroles. Whatever the case, acylation of 3-acylpyrroles is, without doubt, more advantageous, because it utilises easily accessible starting materials. In addition, in all cases tested it has been found to be regiospecific and, under standard conditions, readily provides the required products in very high yields.

In addition, alternative procedures have been developed for the synthesis of 2,4-diacylpyrroles containing the same or different acyl groups based on acylation reactions with 2-substituted 1,3-benzodithiolium and 1,3-benzoxathiolium salts.

In certain particular cases where it is necessary to operate in the presence of protected carbonyl groups, these procedures constitute a secure, albeit laborious, complement to direct acylation.

Experimental

General Details.—^{1}H and ^{13}C NMR spectra were recorded on a Bruker WP 80 SY spectrometer for solutions in deuteriochloroform or in hexadeuterioacetone unless otherwise noted. The chemical shifts are expressed in parts per million (δ) relative to internal tetramethylsilane and J-values are in Hz. Unless otherwise noted, mass spectra were recorded on a double-focusing Kratos MS 80 instrument (operating with direct-inlet system at 70 eV). IR spectra were recorded on a Perkin-Elmer 599 B spectrophotometer for solutions in tetrachloromethane.

Satisfactory elemental analyses were obtained for all the new compounds.

Dichloromethane was dried by removal of its aqueous azeotrope by distillation. Acetonitrile was dried by distillation from phosphorus pentaoxide. Pyridine was dried by distillation from barium oxide. Pyrrole (Fluka) was distilled before use. Light petroleum refers to the fraction boiling in the range 40–70 °C.

2-Substituted 1,3-Benzodithiolium Tetrafluoroborates **13a–h**,[2,15] *2-Substituted 1,3-Benzoxathiolium Tetrafluoroborates* **14a–h**[1,16] *and 2-Acylpyrroles* **4a–h**.[2]—These were prepared as previously reported.

Acylation of Pyrrole **1**. *Typical Procedures.*—(*a*) In entry 1, a solution of benzoyl chloride (1.57 g, 11.2 mmol) in dry CH_2Cl_2 (15 cm^3) was added dropwise at room temp. (~20–25 °C), during 10 min, to a stirred mixture of pyrrole **1** (0.67 g, 10 mmol) and anhydrous $AlCl_3$ (1.60 g, 12 mmol) in the same solvent (15 cm^3). After being stirred at room temp. for 30 min, the reaction mixture was quenched with ice and saturated aq. $NaHCO_3$. The organic phase was separated and combined with the chloroform extracts (3 × 100 cm^3) of the aq. phase and the combined organic phases were washed with water (2 × 50 cm^3), dried on Na_2SO_4, and evaporated under reduced pressure. The crude residue was chromatographed on a silica gel column, with light petroleum–diethyl ether (2:3) as eluent, to afford three products. The first eluted product was 2-benzoylpyrrole **4a** (0.87 g, 51%), m.p. 77–78 °C (from CCl_4–light petroleum) (lit.,[1] 77–78 °C); the second eluted product was 2,4-dibenzoylpyrrole **9a** ($R^1 = R^2$; traces, identified by TLC, MS, ^{1}H NMR); the third eluted product was 3-benzoylpyrrole **5a** (0.14 g, 8%), m.p. 99 °C (from $CHCl_3$–light petroleum) (lit.,[10] 98.5–99 °C).

(*b*) In entry 6, a solution of benzoyl chloride (3.14 g, 22.4 mmol) in dry CH_2Cl_2 (20 cm^3) was added dropwise at room temp. during 20 min to a stirred mixture of pyrrole **1** (0.67 g, 10 mmol) and anhydrous $AlCl_3$ (3.20 g, 24 mmol) in dry CH_2Cl_2 (20 cm^3). Then the reaction mixture was heated until reflux, and reflux was maintained for 72 h until TLC showed that the reaction had stopped. After a work-up identical with that described above, two products were obtained: 2-benzoylpyrrole **4a** (0.08 g, 4%), m.p. 77–78 °C, and 2,4-*dibenzoylpyrrole* **9a** (1.79 g, 65%), m.p. 140 °C (from $CHCl_3$–light petroleum) (Found: C, 78.6; H, 4.8; N, 5.15. $C_{18}H_{13}NO_2$ requires C, 78.53; H, 4.76; N, 5.09%); $\nu_{max}(CCl_4)/cm^{-1}$ 1635 and 1650 (2 CO); $\delta_H(CD_3COCD_3)$ 7.27 (1 H, dd, $J_{1,3}$ 2.45, $J_{3,5}$ 1.38, 3-H), 7.44–7.72 and 7.72–8.05 (11 H, 2 m, 6:5, 2 × Ph and 5-H) and 11.72 (1 H, m, NH); $\delta_C(CDCl_3)$ 120.41 (d, C-3), 125.96 (d, C-5), 128.33, 128.43, 128.82, 129.03, 131.40 and 131.74 (d, CH of Ph), 131.88 (s, C-4), 132.45 (s, C-2), 137.38 and 138.99 (s, C-1 of Ph), 185.67 (s, 2-CO) and 190.45 (s, 4-CO); M, 275.

(*c*) In entry 10, a solution of hexanoyl chloride (1.51 g, 11.2 mmol) in dry CH_2Cl_2 (15 cm^3) was added dropwise at room temp., during 10 min, to a stirred mixture of pyrrole **1** (0.67 g, 10 mmol) and anhydrous $AlCl_3$ (1.60 g, 12 mmol) in dry CH_2Cl_2 (15 cm^3). The mixture was stirred at room temp. for 30 min. Then the reaction mixture was worked up as described above. Chromatography of the crude residue on a silica gel column with light petroleum–diethyl ether (2:3) as eluent afforded three products. The first eluted product was 2-hexanoylpyrrole **4g** (0.86 g, 52%), m.p. 37–39 °C (from pentane) (lit.,[1] 37–39 °C). The second eluted product was 2,4-dihexanoylpyrrole **9g** ($R^1 = R^2$; traces, identified by TLC, MS, ^{1}H NMR). The third eluted product was 3-hexanoylpyrrole **5g** (0.18 g, 11%), m.p. 50 °C (from $CHCl_3$–light petroleum) (lit.,[6] 49–50 °C).

(*d*) In entry 16, a solution of hexanoyl chloride (1.51 g, 11.2 mmol) in dry CH_2Cl_2 (15 cm^3) was added dropwise at room temp., during 10 min, to a mixture of pyrrole **1** (0.67 g, 10 mmol) and anhydrous $AlCl_3$ (1.60 g, 12 mmol) in the same solvent (15 cm^3). After the mixture had been stirred at room temp. for 30 min, a second portion of hexanoyl chloride (1.51 g, 11.2 mmol) and anhydrous $AlCl_3$ (1.60 g, 12 mmol) in dry CH_2Cl_2 (15 cm^3) was added dropwise at room temp., during 10 min. After being stirred at room temp. for a further 30 min, the reaction mixture was refluxed for 7 h until TLC showed the disappearance of the intermediate 2-hexanoylpyrrole **4g**. After work-up identical to that described in (*a*), the crude residue was purified by chromatography on a silica gel column with light petroleum–diethyl ether (2:3) as eluent. Pure 2,4-*dihexanoylpyrrole* **9g** was obtained (1.80 g, 68%), m.p. 76 °C (from $CHCl_3$–light petroleum) (Found: C, 73.0; H, 9.7; N, 5.4. $C_{16}H_{25}NO_2$ requires C, 72.96; H, 9.57; N, 5.32%); $\nu_{max}(CCl_4)/cm^{-1}$ 1650 and 1710 (2 CO); $\delta_H(CDCl_3)$ 0.62–1.06 (6 H, m, 2 × Me), 1.06–1.87 (12 H, m, 6 × CH_2), 2.62–2.97 (4 H, m, 2 × $COCH_2$), 7.39 (1 H, br s, 3-H), 7.76 (1 H, br s, 5-H) and 11.45 (1 H, m, NH); $\delta_C(CDCl_3)$ 13.62 (q, J 125, Me), 22.33, 24.19, 24.55 and 31.34 (t, J 125, CH_2), 37.84 and 39.45 (t, J 125, CH_2CO), 115.38 (d, J 170, C-3), 126.86 (s, C-4), 128.04 (d, J 185, C-5), 132.54 (s, C-2), 192.17 (s, 2-CO) and 195.98 (s, 4-CO); M, 263.

In parallel experiments, a solution of pyrrole in dry CH_2Cl_2 was added dropwise at room temp. to a solution of acyl chloride and anhydrous $AlCl_3$ in the same solvent. In all the above reactions, the same products were obtained with the same yields.

Acylation of 2-Acylpyrroles **4**.—*2,4-Dihexanoylpyrrole* **9g**. *Typical procedure.* In entry 37, a solution of hexanoyl chloride (1.51 g, 11.2 mmol) in dry CH_2Cl_2 (5 cm^3) was slowly added at room temp. (~20–25 °C) to a stirred suspension of anhydrous $AlCl_3$ (3.20 g, 24 mmol) in the same solvent (20 cm^3) and the mixture was stirred at room temp. for 10 min. Then a solution of 2-hexanoylpyrrole **4g** (1.65 g, 10 mmol) in dry CH_2Cl_2 (15 cm^3) was added dropwise at room temp. during 10 min, and the resulting solution was refluxed for 9 h until TLC showed the disappearance of substrate **4g**. After work-up identical with that described above for the acylation of pyrrole, the crude residue was speedily chromatographed on a short silica gel column with light petroleum–diethyl ether (2:3) as eluent to afford the title compound **9g** (2.56 g, 94%), m.p. 76 °C (from $CHCl_3$–light petroleum). Spectral data were identical with those of the sample obtained in the acylation of pyrrole.

2,4-Bis(4-methoxybenzoyl)pyrrole **9c**. *Typical procedure.* In entry 27, a solution of 4-methoxybenzoyl chloride (2.86 g, 16.8 mmol) in dry CH_2Cl_2 (7 cm^3) was slowly added at room temp. to a stirred suspension of anhydrous $AlCl_3$ (4.00 g, 30 mmol) in the same solvent (25 cm^3) and the mixture was stirred at room temp. for 10 min. A solution of 2-(4-methoxybenzoyl)pyrrole **4c** (2.01 g, 10 mmol) in dry CH_2Cl_2 (15 cm^3) was added dropwise at room temp. during 10 min, and the resulting solution was refluxed until disappearance of the starting material **4c** (5 h). After work-up identical with that described above, the crude

residue was chromatographed on a silica gel column with light petroleum–diethyl ether (2:3) as eluent to afford two products. The first eluted product was 2,5-bis(4-methoxybenzoyl)pyrrole **12b** (1.07 g, 32%), m.p. 189–190 °C (from $CHCl_3$–MeOH) (lit.,[1] m.p. 189–190 °C). The second eluted product was the *title compound* **9c** (2.28 g, 68%), m.p. 168 °C (from $CHCl_3$–light petroleum) (Found: C, 71.7; H, 5.15; N, 4.3. $C_{20}H_{17}NO_4$ requires C, 71.63; H, 5.11; N, 4.18%); $\nu_{max}(CCl_4)/cm^{-1}$ 1605 and 1630 (2 CO); $\delta_H(CD_3COCD_3)$ 3.89 and 3.90 (6 H, 2 s, 1:1, 2 × OMe), 7.07, 7.10, 7.77 and 7.92 (8 H, 4 d, 1:1:1:1, *J* 8.00, Ph), 7.31 (1 H, t, $J_{1,3} = J_{3,5} = 1.50$, 3-H), 7.77 (1 H, t, $J_{1,5} = J_{3,5} = 1.50$, 5-H) and 11.57 (1 H, m, NH); $\delta_C(CDCl_3)$ 55.32 (q, *J* 140, OMe), 113.61, 113.78, 131.15 and 131.34 (d, *J* 165, CH of Ph), 131.70 and 131.72 (s, C-1 of Ph), 162.77 and 163.26 (s, *C*–OMe), 119.29 (d, *J* 170, C-3), 126.11 (d, C-5), 129.72 (s, C-4), 130.02 (s, C-2), 184.13 (s, 2-CO) and 189.08 (s, 4-CO); *M*, 336.

3-*Acyl*-1-*phenylsulfonylpyrroles* **2a–e, g, h**. *General procedure*. Under conditions similar to those previously reported,[9,10] a solution of acyl chloride (11.2 mmol) in dry CH_2Cl_2 (5 cm^3) was slowly added, at room temp., to a stirred suspension of anhydrous $AlCl_3$ (1.60 g, 12 mmol) in the same solvent (20 cm^3) and the resulting solution was stirred for 10 min. A solution of 1-phenylsulfonylpyrrole[10] (2.07 g, 10 mmol) in dry CH_2Cl_2 (20 cm^3) was added dropwise at room temp. during 10 min, and the mixture was stirred for a further 30 min. Then the reaction mixture was treated with ice–water and the product was extracted with chloroform (3 × 80 cm^3). The collected extracts were washed successively with 5% aq. $NaHCO_3$ (2 × 50 cm^3) and water (50 cm^3), dried, and evaporated. The crude residue was purified by rapid chromatography on a short silica gel column with light petroleum–diethyl ether (2:3) as eluent. Yields of pure products **2a–e, g, h** were 82–100%.

3-*Pivaloyl*-1-*phenylsulfonylpyrrole* **2f**. The reaction was carried out as described above using $SnCl_4$ as Lewis acid. The following molar proportions of the reagents were necessary to complete the reaction: 1-phenylsulfonylpyrrole:pivaloyl chloride:$SnCl_4$ = 1:2.8:3. The reaction time at room temp. was 2.5 h and the chromatographic solvent was light petroleum–diethyl ether (2:3). Pure compound **2f** was obtained as the only product* (2.38 g, 82%), m.p. 85–86 °C (from CCl_4–light petroleum) (Found: C, 61.75; H, 5.8; N, 4.7; S, 11.1. $C_{15}H_{17}NO_3S$ requires C, 61.83; H, 5.88; N, 4.81; S, 11.00%); $\nu_{max}(CCl_4)/cm^{-1}$ 1655 (CO); $\delta_H(CDCl_3)$ 1.30 (9 H, s, t-C_4H_9), 6.75 (1 H, dd, $J_{2,4}$ 2.00, $J_{4,5}$ 3.20, 4-H), 7.15 (1 H, dd, $J_{2,5}$ 2.00, $J_{4,5}$ 3.20, 5-H), 7.77 (1 H, t, $J_{2,4} = J_{2,5}$ = 2.00, 2-H) and 7.42–7.71 and 7.84–8.05 (5 H, 2 m, 2:3, Ph); $\delta_C(CDCl_3)$ 27.08 (q, *J* 125, Me), 43.22 (s, *C*Me_3), 113.82 (d, *J* 175, C-4), 120.22 (d, *J* 190, C-2), 123.90 (d, *J* 190, C-5), 125.87 (s, C-3), 126.60, 129.21 and 134.05 (d, C of Ph) and 137.68 (s, C-1 of Ph); *M*, 291.

3-*Acylpyrroles* **5a–h**. *General Procedure*.—Under conditions similar to those previously reported,[9] aq. NaOH (0.6 g, 15 mmol in 3.5 cm^3) was added to a solution of a 3-acyl-1-phenylsulfonylpyrrole **2a–h** (10 mmol) in the least amount of dioxane (7–10 cm^3). The reaction mixture was stirred at room temp. for *ca.* 15 h (24 h for **2f**) until completion of the hydrolysis (TLC: SiO_2, chloroform) and was then poured into water and extracted with chloroform (3 × 80 cm^3). Extracts were washed successively with 5% aq. NaOH (80 cm^3) and with water (2 × 80 cm^3), dried, and filtered through a small layer of silica gel with chloroform as eluent. Pure compounds **5a–h** were obtained in 95–100% yield.

* On the other hand, the reaction of 1-phenylsulfonylpyrrole, benzoyl chloride and $SnCl_4$ in the molar proportions 1:2.8:3 afforded two products: 3-benzoyl-1-phenylsulfonylpyrrole **2a** and 2-benzoyl-1-phenylsulfonylpyrrole. The yields were 23 and 77%, respectively.

Hydrolysis of 3-(4-*Chlorobenzoyl*)-1-*phenylsulfonylpyrrole* **2d**.—(*a*) Under conditions similar to those reported,[10] 10% aq. KOH (11.2 cm^3) was added to a solution of compound **2d** (3.45 g, 10 mmol) in 1,4-dioxane–methanol (10:8 cm^3) and the reaction mixture was stirred at room temp. until disappearance of substrate **2d** (1 h). The crude residue obtained after the usual work-up was chromatographed on a silica gel column with light petroleum–diethyl ether (2:3) as eluent to afford two products. The first eluted product was 3-(4-chlorobenzoyl)-1-methylpyrrole (0.42 g, 19%), m.p. 51–52 °C (from hexane) (lit.,[1] 51–52 °C); *M*, 219; spectral data were identical with those of a sample previously prepared.[1] The second eluted product was 3-(4-chlorobenzoyl)pyrrole **5d** (1.62 g, 79%), m.p. 120 °C (from $CHCl_3$–light petroleum) (lit.,[10] 119–120 °C).

Identical results were obtained when NaOH was used instead of KOH.

(*b*) The reaction requires anhydrous conditions and was conducted in oven-dried (130 °C) glassware under nitrogen. Sodium methoxide (0.70 g, 13 mmol; Aldrich) was added to a solution of compound **2d** (3.45 g, 10 mmol) in dry 1,4-dioxane (30 cm^3; Aldrich) and the mixture was stirred at room temp. for 24 h. Work-up as described above gave 3-(4-chlorobenzoyl)-1-methylpyrrole and 3-(4-chlorobenzoyl)pyrrole in 78 (1.71 g) and 14% (0.29 g) yield, respectively.

Acylation of 3-*Acylpyrroles* **5**. *General Procedure*.—A solution of acyl chloride (11.2 mmol) in dry CH_2Cl_2 (5 cm^3) was slowly added, at room temp. (~20–25 °C) to a stirred suspension of anhydrous $AlCl_3$ (3.20 g, 24 mmol) in the same solvent (20 cm^3). After 10 min, a solution of 3-acylpyrrole **5a–e, g, h** (10 mmol) was added dropwise at room temp., during 10 min, and the resulting solution was stirred for 30 min again until disappearance of the starting compound **5**. Work-up described above for the acylation of pyrrole afforded 2,4-diacylpyrroles **9a–e, g–l** as the only products. These were further purified by speedy chromatography on a short silica gel column (20 cm in height and 4–5 cm in diameter) using as eluent light petroleum–diethyl ether (2:3) for products **9a, c, e, g, h, j, l** and chloroform for compounds **9b, d, i, k**. Yields of pure compounds **9** were 91–100%.

2,4-*Dipivaloylpyrrole* **9f**. The reaction was carried out as described above, with $SnCl_4$ as Lewis acid. The following molar proportions of the reagents were necessary to complete the reaction: 3-pivaloylpyrrole **5f**:pivaloyl chloride:$SnCl_4$ = 1:2.8:6. The reaction time at room temp. was 2 h and the chromatographic solvent was light petroleum–ethyl ether (2:3). Pure compound **9f** was obtained (1.90 g, 81%), m.p. 140–141 °C (from $CHCl_3$–light petroleum) (Found: C, 71.5; H, 9.05; N, 6.0. $C_{14}H_{21}NO_2$ requires C, 71.46; H, 9.00; N, 5.95%); $\nu_{max}(CCl_4)/cm^{-1}$ 1645, 1660 (2 CO); $\delta_H(CDCl_3)$ 1.35, 1.38 (18 H, 2 s, 1:1, 2 × t-C_4H_9), 7.47 (1 H, dd, $J_{1,3}$ 3.00, $J_{3,5}$ 1.70, 3-H), 7.65 (1 H, dd, $J_{1,5}$ 3.00, $J_{3,5}$ 1.70, 5-H) and 9.99 (1 H, m, NH); $\delta_C(CDCl_3)$ 27.35, 28.00 (q, CH_3, *J* 125), 42.91, 43.62 (s, *C*Me_3), 117.02 (d, *J* 170, C-3), 124.05 (s, C-4), 126.93 (d, *J* 185, C-5), 128.90 (s, C-2), 197.50 (s, 2-CO) and 201.34 (s, 4-CO); *M*, 235.

Collateral proof. The reaction carried out with the usual molar proportions of the reagents, *i.e.* **5f**:pivaloyl chloride:$SnCl_4$ = 1:1.12:2.40, afforded **9f** in 56% yield and the starting **5f** was recovered in 25% yield. When the molar proportions of the reagents was 1:1.12:6, **5f** disappeared and **9f** was obtained in 67% yield.

4-*Benzoyl*-2-(2-*phenyl*-1,3-*benzodithiol*-2-*yl*)*pyrrole* **8a**. *Typical Procedure*.—Under conditions similar to those previously reported,[2] 2-phenyl-1,3-benzodithiolium tetrafluoroborate **13a** (4.00 g, 12.5 mmol) was added in one portion to a stirred mixture of 3-benzoylpyrrole **5a** (1.71 g, 10 mmol) and dry pyridine (0.99 g, 12.5 mmol) in dry acetonitrile (25–30 cm^3) and the mixture was heated in an oil-bath at 60 °C for 2 h. Progress

of the reaction was monitored by TLC (SiO_2; chloroform). Two other portions of the salt **13a** and pyridine were then added after 1 and 2 h, respectively [each of **13a** (0.79 g, 2.5 mmol) and of pyridine (0.20 g, 2.5 mmol)] and the mixture was heated at 60 °C until completion of the reaction (5 h in all). The resulting precipitate was gathered by filtration, washed with a small amount of acetonitrile (5 cm^3), and then dissolved in chloroform–water (300:100 cm^3) which was washed successively with 5% aq. NaOH (2 × 80 cm^3) and water (80 cm^3), dried, and evaporated under reduced pressure. The residue was pure *title compound* **8a** (2.70 g, 68%). Also, the mother liquor was worked up as described for the precipitate and the crude residue was chromatographed on a silica gel column with chloroform as eluent, to afford a further crop (0.74 g) of *compound* **8a**; overall yield was 86%, m.p. 213 °C (from $CHCl_3$–EtOH) (Found: C, 72.2; H, 4.35; N, 3.6; S, 16.1. $C_{24}H_{17}NOS_2$ requires C, 72.15; H, 4.29; N, 3.51; S, 16.05%); $\nu_{max}(CCl_4)/cm^{-1}$ 1635 (CO); $\delta_H(CD_3COCD_3)$ 6.95 (1 H, dd, $J_{1,3}$ 2.60, $J_{3,5}$ 2.00, 3-H), 7.32–7.50 (1 H, m, 5-H), 6.95–7.32 and 7.50–7.77 (14 H, 2 m, 2:5, 4 H of benzodithiole and 2 × Ph) and 10.93 (1 H, m, NH); $\delta_C(CDCl_3)$ 71.71 (s, SCS), 111.52 (d, C-3), 122.74 (d, C-5), 130.90 (s, C-4), 133.88 (s, C-2), 121.93 and 126.00 (d, C of benzodithiole), 136.96 (s, CS of benzodithiole), 127.62, 127.90 and 128.13 (d, C of Ph), 139.58 and 140.43 (s, C-1 of Ph) and 188.77 (s, CO); *M*, 399.

3-(2-*Phenyl*-1,3-*benzodithiol*-2-*yl*)-1-*phenylsulfonylpyrrole* **3a**. *Typical Procedure*.—According to the general procedure previously reported for the preparation of 2-substituted 1,3-benzodithioles,[17] a mixture of 3-benzoyl-1-phenylsulfonylpyrrole **2a** (3.11 g, 10 mmol), benzene-1,2-dithiol (1.56 g, 11 mmol) and HBF_4–diethyl ether complex (54%; 1 cm^3) in dry benzene (10 cm^3) was refluxed and stirred for 4–5 h until disappearance of substrate **2a** (TLC, light petroleum–diethyl ether, 4:1). After cooling, compound **3a** began to precipitate; dry diethyl ether was added to complete the precipitation. Then the solid was gathered by filtration and washed with dry diethyl ether. The yield of virtually pure (TLC, NMR) *compound* **3a** was 96% (4.18 g); the product was directly used in the following step. M.p. 171 °C (from $CHCl_3$) (Found: C, 63.5; H, 4.0; N, 3.3; S, 22.15. $C_{23}H_{17}NO_2S_3$ requires C, 63.42; H, 3.93; N, 3.21; S, 22.08%); $\delta_H(CD_3COCD_3)$ 6.41 (1 H, t, $J_{2,4} = J_{4,5}$ = 2.53, 4-H) and 7.00–7.50 and 7.50–7.92 (16 H, 2 m, 9:7, 2 × Ph, 4 H of benzodithiole, and 2- and 5-H); $\delta_C(CDCl_3)$ 72.00 (s, SCS), 113.07 (d, *J* 170, C-4), 119.47 and 120.17 (d, C-2 and -5), 120.78, 124.50, 125.08, 126.46, 126.64 and 127.87 (d, C of Ph, and C of benzodithiole), 132.26 (s, C-1 of Ph) and 138.00 (s, CS); *M*, 435.

3-(2-*Phenyl*-1,3-*benzodithiol*-2-*yl*)*pyrrole* **6a**. *Typical Procedure*.—In conditions similar to those described above for the hydrolysis of compounds **2**, a mixture of the dithioketal **3a** (4.35 g, 10 mmol) and 10% aq. KOH (11.2 cm^3, 20 mmol) in 1,4-dioxane–methanol (2:1, 50 cm^3) was heated at 50 °C and stirred. When a solution was obtained (*ca.* 15 min) a TLC test (SiO_2; light petroleum–diethyl ether, 7:3) showed the disappearance of substrate **3a**. Then the reaction mixture was poured into water and extracted with chloroform (3 × 100 cm^3); the extract was washed successively with 5% aq. NaOH (2 × 80 cm^3) and water (2 × 80 cm^3), dried, and evaporated under reduced pressure. Virtually pure *title compound* **6a** (TLC, NMR) was obtained in quantitative yield (2.95 g); it was directly used in the following step. M.p. 112 °C (from $CHCl_3$–light petroleum) (Found: C, 69.2; H, 4.5; N, 4.8; S, 21.8. $C_{17}H_{13}NS_2$ requires C, 69.12; H, 4.43; N, 4.74; S, 21.70%); $\delta_H(CD_3COCD_3)$ 6.29 (1 H, 6 lines, $J_{1,4} = J_{4,5}$ = 2.58, $J_{2,4}$ 2.20, 4-H), 6.52–6.64 (1 H, m, 5-H), 6.73 (1 H, 6 lines, $J_{1,2} = J_{2,5}$ = 2.62, $J_{2,4}$ 2.20, 2-H), 6.95–7.42 (7 H, m, 4 H of benzodithiole, 3 H of Ph), 7.71–7.97 (2 H, m, Ph) and 9.89 (1 H, m, NH); $\delta_C(CDCl_3)$ 77.05 (s, SCS), 108.96 (d, *J* 170, C-4), 118.38 (d, *J* 190, C-2 and -5), 121.92 and 125.61 (d, *J* 160, CH of benzodithiole), 126.55 (s, C-3), 127.60 and 127.83 (d, *J* 160, CH of Ph), 138.35 (s, SC of benzodithiole and 143.81 (s, C-1 of Ph); *M*, 295.

4-(2-*Phenyl*-1,3-*benzodithiol*-2-*yl*)-2-(2-*phenyl*-1,3-*benzoxathiol*-2-*yl*)*pyrrole* **7a**. *Typical Procedure*.—Under conditions similar to those previously reported,[1] 3-(2-phenyl-1,3-benzodithiol-2-yl)pyrrole **6a** (2.95 g, 10 mmol) was dissolved, by heating, in dry acetonitrile (10 cm^3). Dry pyridine (0.99 g, 12.5 mmol) and then 2-phenyl-1,3-benzoxathiolium tetrafluoroborate **14a** (3.76 g, 12.5 mmol) were added in one portion to the stirred mixture. The reaction was exothermic, the salt **14a** dissolved at once, and a plentiful precipitate was formed. After addition of more dry acetonitrile (10 cm^3), the mixture was stirred for 30 min further, until a TLC test showed the disappearance of substrate **6a**. The precipitate was gathered by filtration, washed with a small amount of dry acetonitrile (2 cm^3), and then treated with a mixture of chloroform–water (300:100 cm^3). The organic layer was separated, washed successively with 5% aq. NaOH (2 × 80 cm^3) and water (80 cm^3), dried, and evaporated under reduced pressure. The residue was pure *compound* **7a** (4.68 g). Also, the mother liquor was worked up as described for the precipitate; by chromatography of the residue on a silica gel column with light petroleum–diethyl ether 3:2 as eluent, a further crop of **7a** (0.24 g) was recovered; overall yield was 97%. M.p. 103 °C (from acetone) (Found: C, 70.9; H, 4.1; N, 2.7; S, 19.0. $C_{30}H_{21}NOS_3$ requires C, 70.97; H, 4.14; N, 2.76; S, 18.94); $\delta_H(CD_3COCD_3)$ 6.21 (1 H, dd, $J_{1,3}$ 3.00, $J_{3,5}$ 1.90, 3-H), 6.75 (1 H, dd, $J_{1,5}$ 3.00, $J_{3,5}$ 1.90, 5-H), 6.91–7.52 (14 H, m, 8 H of benzodithiole, 6 H of Ph), 7.52–7.75 and 7.75–7.96 (4 H, 2 m, 1:1, Ph) and 10.57 (1 H, m, NH); δ_C 72.75 (s, SCS), 98.00 (s, OCS), 110.67 (d, *J* 170, C-3), 121.66 (d, *J* 180, C-5), 111.63, 120.60, 121.83, 122.69, 125.58 and 128.26 (d, C of benzodithiole and benzoxathiole), 126.49 (s, CS of benzoxathiolyl), 126.22, 127.56, 127.86, 128.39 and 128.54 (d, C of Ph), 128.80 (s, C-4), 131.52 (s, C-2), 138.21 (s, CS of benzodithiolyl), 141.76 and 143.44 (s, C-1 of Ph) and 153.98 (s, CO); *M*, 507.

2-*Benzoyl*-4-(2-*phenyl*-1,3-*benzodithiol*-2-*yl*)*pyrrole* **11a**. *Typical Procedure*.—HBF_4–Diethyl ether complex (54%; 8.15 g, 50 mmol) was added, at room temp., to a stirred solution of compound **7a** (2.54 g, 5 mmol) in absolute EtOH (200 cm^3). The solution immediately changed colour to red, then to orange, and lastly to light yellow and a precipitate began to separate. The mixture was stirred for 1 h until substrate **7a** disappeared (TLC: SiO_2; light petroleum–diethyl ether, 2:3). Then the reaction mixture was poured into water and extracted repeatedly with chloroform (3 × 100 cm^3); the extract was washed successively with 5% aq. NaOH (2 × 100 cm^3) and water (2 × 100 cm^3), dried, and evaporated under reduced pressure. Virtually pure (TLC, NMR) *title compound* **11a** was obtained in quantitative yield (2.00 g). It was directly used in the following step. M.p. 153–154 °C (from CCl_4–light petroleum) (Found: C, 72.2; H, 4.35; N, 3.6; S, 16.1. $C_{24}H_{17}NOS_2$ requires C, 72.15; H, 4.29; N, 3.51; S, 16.05%); $\nu_{max}(CCl_4)/cm^{-1}$ 1635 (CO); $\delta_H(CDCl_3)$ 6.90–7.56 (12 H, m, 4 H of benzodithiole, 6 H of Ph, and 3- and 5-H), 7.72–7.95 (4 H, m, Ph) and 10.00 (1 H, m, NH); $\delta_C(CDCl_3)$ 73.00 (s, SCS), 122.08 and 125.90 (d, C of benzodithiole), 127.92, 128.31, 128.96 and 131.98 (d, C of Ph), 129.74 (s, C-4), 130.97 (s, C-2), 137.94 (s, CS of benzodithiole), 138.01 and 142.59 (s, C-1 of Ph) and 185.06 (s, CO); *M*, 399.

2,4-*Bis*(2-*phenyl*-1,3-*benzodithiol*-2-*yl*)*pyrrole* **10a**. *Typical Procedure*.—Under conditions similar to those above reported for the preparation of compound **8a**, 2-phenyl-1,3-benzodithiolium tetrafluoroborate **13a** (4.00 g, 12.5 mmol) was added, in one portion, to a stirred mixture of 3-(2-phenyl-1,3-benzodi-

thiol-2-yl)pyrrole **6a** (2.95 g, 10 mmol) and dry pyridine (0.99 g, 12.5 mmol) in dry acetonitrile (10 cm^3). The reaction was exothermic, the salt dissolved at once, and a plentiful precipitate was formed. The mixture was stirred for 10 min further, until TLC showed the disappearance of substrate **6a** (SiO_2; light petroleum–diethyl ether, 7:3). The precipitate was gathered by filtration, washed with a small amount of dry acetonitrile (2 cm^3), and then treated with chloroform–water (300:100 cm^3). The organic layer was separated, dried, and evaporated under reduced pressure. Virtually pure *title compound* **10a** was obtained in quantitative yield (5.23 g); it was directly used in the following step. M.p. 156 °C (from $CHCl_3$–light petroleum) (Found: C, 68.7; H, 4.1; N, 2.7; S, 24.55. $C_{30}H_{21}NS_4$ requires C, 68.80; H, 4.04; N, 2.67; S, 24.48%); $\delta_H(CD_3COCD_3)$ 6.25 (1 H, dd, $J_{1,3}$ 2.84, $J_{3,5}$ 1.90, 3-H), 6.61 (1 H, dd, $J_{1,5}$ 2.73, $J_{3,5}$ 1.90, 5-H), 6.92–7.47 (14 H, m, 8 H of benzodithiole and 6 H of Ph) and 7.67–8.00 (4 H, m, Ph); $\delta_C(CDCl_3)$ 119.60 (d, C-5), 121.91, 122.13, 125.63 and 126.08 (d, CH of benzodithiole), 127.61, 127.94 and 128.05 (d, CH of Ph), 128.29 (s, C-4), 132.00 (s, C-2), 138.00 and 139.00 (s, SC of benzodithiole) and 144.5 (s, C-1 of Ph); *M*, 523.

Hydrolysis of 4-*Acyl*-2-(2-*substituted* 1,3-*Benzodithiol*-2-*yl*)-*pyrroles* **8** *and* 2-*Acyl*-4-(2-*substituted* 1,3-*Benzodithiol*-2-*yl*)*pyrroles* **11**.—2,4-*Dibenzoylpyrrole* **9a**. *Typical procedures*. (*a*) According to the procedure previously reported,[2] a solution of compound **8a** (2.00 g, 5 mmol) in DMSO (40 cm^3) was added to a stirred solution of the hydrolysis reagent constituted by red HgO (2.17 g, 10 mmol) in a mixture of DMSO (5 cm^3) and 35% aq. HBF_4 (5 cm^3). The solution obtained was heated at ~60 °C until disappearance of substrate **8a** (2 h; TLC: SiO_2; $CHCl_3$). The reaction mixture was then treated with 10% aq. KI (60 cm^3) and extracted with chloroform (4 × 70 cm^3). The collected organic layers were washed successively with 10% aq. KI (2 × 50 cm^3), water (50 cm^3), 5% aq. NaOH (2 × 50 cm^3), and water (50 cm^3). The crude residue, obtained after evaporation of the solvent, was purified by rapid chromatography on a small silica gel column with chloroform as eluent. Pure **9a** was obtained in quantitative yield (1.38 g); m.p. 140 °C (from $CHCl_3$–light petroleum); spectral data were identical with those reported above.

(*b*) A mixture of substrate **11a** (2.00 g, 5 mmol), red HgO (2.17 g, 10 mmol), 35% aq. HBF_4 (5 cm^3) and DMSO (45 cm^3) was stirred at room temp. for 30 min, until completion of hydrolysis. The reaction mixture was worked up as described above to give pure compound **9a** (1.29 g, 94%).

Hydrolysis of 2,4-*Bis*(2-*substituted* 1,3-*Benzodithiol*-2-*yl*)-*pyrroles* **10**.—2,4-*Dibenzoylpyrrole* **9a**. *Typical procedure*. The mixture of 2,4-bis(2-phenyl-1,3-benzodithiol-2-yl)pyrrole **10a** (2.62 g, 5 mmol), red HgO (4.34 g, 20 mmol), 35% aq. HBF_4 (10 cm^3) and DMSO (90 cm^3) was heated at ~60 °C and stirred until compound **10a** was no longer present and the intermediate 4-benzoyl-2-(2-phenyl-1,3-benzodithiol-2-yl)pyrrole **8a** formed during the hydrolysis had disappeared. Hydrolysis was complete after 1 h. The reaction mixture was worked up as described above to give pure compound **9a** (1.29 g, 94%).

4-*Benzoyl*-2-(2-*phenyl*-1,3-*benzodithiol*-2-*yl*)*pyrrole* **8a**. *Typical procedure*. The reaction mixture of substrate **10a** (2.62 g, 5 mmol), red HgO (2.17 g, 10 mmol), 35% aq. HBF_4 (5 cm^3) and DMSO (50 cm^3) was stirred at room temp. for 30 min until the starting compound **10a** was no longer present. The work-up described above afforded pure **8a** (1.68 g, 86%), m.p. 214 °C (from $CHCl_3$–EtOH); spectral data were identical with those of the sample prepared above by reaction of compound **5a** with the salt **13a**.

2-(2-*Cyclohexyl*-1,3-*benzodithiol*-2-*yl*)-4-*cyclohexylcarbonylpyrrole* **8h**. Prepared in the same way and with the same ratio of reagents, starting from compound **10h** (2.68 g, 5 mmol). The reaction time at room temp. was 1 h. Pure *title compound* **8h** was obtained (1.87 g, 91%), identical with the sample prepared by reaction of compound **5h** with the salt **13h**: m.p. 240 °C (from $CHCl_3$–EtOH) (Found: C, 70.1; H, 7.15; N, 3.4; S, 15.5. $C_{24}H_{29}NOS_2$ requires C, 70.03; H, 7.10; N, 3.40; S, 15.58%); $\nu_{max}(CCl_4)/cm^{-1}$ 1650 (CO); $\delta_H(CDCl_3)$ 0.95–2.10 and 2.67–3.05 (22 H, 2 m, 1:10, 2 × c-C_6H_{11}), 6.72 (1 H, dd, $J_{1,3}$ 2.60, $J_{3,5}$ 2.00, 3-H), 6.90–7.20 (m, 4 H of benzodithiole), 7.20–7.35 (1 H, m, 5-H) and 9.02 (1 H, m, NH); *M*, 411.

2-(2-tert-*Butyl*-1,3-*benzodithiol*-2-*yl*)-4-*pivaloylpyrrole* **8f**. Prepared in the same way by starting from a mixture of substrate **10f** (2.42 g, 5 mmol), red HgO (4.34 g, 20 mmol), 35% aq. HBF_4 (10 cm^3) and DMSO (50 cm^3). The reaction time was 5 h at 60 °C. Pure *title compound* **8f** was obtained (1.73 g, 96%), identical with the sample prepared by reaction of compound **5f** with the salt **13f**: m.p. 258 °C (from $CHCl_3$–light petroleum) (Found: C, 66.75; H, 6.9; N, 4.0; S, 17.9. $C_{20}H_{25}NOS_2$ requires C, 66.81; H, 7.01; N, 3.90; S, 17.83%); $\nu_{max}(CCl_4)/cm^{-1}$ 1640 (CO); $\delta_H(CDCl_3)$ 1.22 (9 H, s, Bu^t), 1.29 (9 H, s, Bu^{t}CO), 6.87–7.22 (6 H, m, 3- and 5-H, and 4 H of benzodithiole) and 8.91 (1 H, m, NH); *M*, 359.

Friedel–Crafts Reaction on 3-(2-*Phenyl*-1,3-*benzodithiol*-2-*yl*)*pyrrole* **6a**.—(*a*) A solution of benzoyl chloride (1.57 g, 11.2 mmol) in dry CH_2Cl_2 (5 cm^3) was added dropwise at room temp. to a stirred suspension of anhydrous $AlCl_3$ (1.60 g, 12 mmol) in the same solvent (15 cm^3) and the mixture was stirred for 10 min. A solution of compound **6a** (2.95 g, 10 mmol) in dry CH_2Cl_2 (10 cm^3) was added dropwise at room temp. during 10 min, and the mixture was stirred for a further 2 h until the disappearance of substrate **6a**. Usual work-up afforded a crude residue, which was chromatographed on a silica gel column, with light petroleum–diethyl ether (2:3) as eluent, to afford two products. The first eluted product was 2-benzoyl-4-(2-phenyl-1,3-benzodithiol-2-yl)pyrrole **11a** (1.32 g, 33%), m.p. 153–154 °C; it was identical with the sample above prepared by hydrolysis of bis-ketal **7a**. The second eluted product was 3-benzoylpyrrole **5a** (0.91 g, 53%), m.p. 99 °C (from $CHCl_3$–light petroleum).

(*b*) Under the same conditions, the reaction of compound **6a** (2.95 g, 10 mmol) with 4-toluoyl chloride (1.73 g, 11.2 mmol) and anhydrous $AlCl_3$ (1.60 g, 12 mmol) in dry CH_2Cl_2 (10 cm^3) afforded two products: 3-benzoylpyrrole **5a** (0.65 g, 38%), m.p. 99 °C (from $CHCl_3$–light petroleum) and 4-(2-*phenyl*-1,3-*benzodithiol*-2-*yl*)-2-(4-*toluoyl*)*pyrrole* **11p** (1.73 g, 42%), m.p. 200–201 °C (from $CHCl_3$–light petroleum) (Found: C, 72.7; H, 4.7; N, 3.4; S, 15.6. $C_{25}H_{19}NOS_2$ requires C, 72.61; H, 4.63; N, 3.39; S, 15.50%); $\nu_{max}(CCl_4)/cm^{-1}$ 1610 and 1630 (CO); $\delta_H(CDCl_3)$ 2.44 (3 H, s, Me), 6.95–7.44 (11 H, m, 4 H of benzodithiole, Ph, and 3- and 5-H), 7.67–7.95 (4 H, m, Ph) and 9.81 (1 H, m, NH); $\delta_C(CDCl_3)$ 29.00 (q, Me), 75.00 (s, SCS), 110.50 (d, C-3), 119.30 (d, C-5), 122.03 and 125.34 (d, CH of benzodithiole), 127.88 and 129.05 (d, CH of Ph), 125.87 (s, C-4), 130.50 (s, C-2), 137.50 (s, CS) and 138.00 and 139.50 (s, C-1 of Ph, CCH_3); *M*, 413.

Reaction of 2-*Benzoylpyrrole* **4a** *and* 2-*Phenyl*-1,3-*benzodithiolium Tetrafluoroborate* **13a**.—A mixture of 2-benzoylpyrrole **4a** (1.71 g, 10 mmol), 2-phenyl-1,3-benzodithiolium tetrafluoroborate **13a** (3.95 g, 12.5 mmol) and dry pyridine (0.99 g, 12.5 mmol) in dry acetonitrile (10 cm^3) was stirred and heated at ~70 °C for 2 h. Progress of the reaction was monitored by TLC (SiO_2; $CHCl_3$). Five portions of the salt **13a** and pyridine (each of 0.79 g, 2.5 mmol for **13a**, and of 0.20 g, 2.5 mmol for pyridine) were again added at intervals of 30 min, and the mixture was heated for 8 h in all. Successive TLC tests showed that the reaction had stopped. The reaction mixture was then treated with chloroform–water (300:100 cm^3). The organic layer was

separated, washed successively with 5% aq. NaOH (2 × 80 cm^3) and water (2 × 80 cm^3), dried, and evaporated under reduced pressure. The residue was chromatographed on a silica gel column, with chloroform as eluent, to afford three products. The first eluted product was 2-*benzoyl*-5-(2-*phenyl*-1,3-*benzodithiol*-2-*yl*)*pyrrole* **15** (1.76 g, 44%), m.p. 189–190 °C (from $CHCl_3$–light petroleum) (Found: C, 72.2; H, 4.3; N, 3.6; S, 16.1. $C_{24}H_{17}NOS_2$ requires C, 72.15; H, 4.29; N, 3.51; S, 16.05%); $\nu_{max}(CCl_4)/cm^{-1}$ 1610 and 1625 (CO); $\delta_H(CDCl_3)$ 6.25 (1 H, dd, $J_{1,4}$ 2.00, $J_{3,4}$ 3.70, 4-H), 6.66 (1 H, dd, $J_{1,3}$ 2.00, $J_{3,4}$ 3.70, 3-H), 6.75–7.60 (10 H, m, 4 H of benzodithiole and 6 H of Ph), 7.60–7.97 (4 H, m, Ph) and 9.83 (1 H, br s, NH); $\delta_C(CDCl_3)$ 70.00 (s, SCS), 112.63 and 119.07 (d, *J* 170, C-3 and -4), 122.18 and 126.23 (d, CH of benzodithiole), 127.92, 128.15, 128.41, 128.60, 128.91 and 129.03 (d, CH of Ph), 131.77 and 132.48 (s, C-2 and -5), 137.08 (s, CS), 139.80 and 140.64 (s, C-1 of Ph) and 186.02 (s, CO); *M*, 399. The second eluted product was 2-benzoyl-4-(2-phenyl-1,3-benzodithiol-2-yl)pyrrole **11a** (1.16 g, 29%), m.p. 153–154 C (from CCl_4–light petroleum), identical with the sample obtained as described above by hydrolysis of compound **7a**. The third eluted product was the starting 2-benzoylpyrrole **4a** (0.46 g, 27%), m.p. 77–78 °C (from CCl_4–light petroleum).

Supplementary Material.—^1H and ^{13}C NMR spectroscopic data for 3-acyl-1-phenylsulfonylpyrroles **2**, 4-acyl-2-(2-substituted 1,3-benzodithiol-2-yl)pyrroles **8**, 2,4-diacylpyrroles **9** and 2-acyl-4-(2-substituted 1,3-benzodithiol-2-yl)pyrroles **11**; ^1H NMR spectroscopic data of 1-phenylsulfonyl-3-(2-substituted 1,3-benzodithiol-2-yl)pyrroles **3**, 3-(2-substituted 1,3-benzodithiol-2-yl)pyrroles **6**, 4-(2-substituted 1,3-benzodithiol-2-yl)-2-(2-substituted 1,3-benzoxathiol-2-yl)pyrroles **7**, and 2,4-bis(2-substituted 1,3-benzodithiol-2-yl)pyrroles **10**; and elemental analysis data for compounds **2**, **3** and **6**–**11** have been deposited at the British Library Document Supply Centre. Suppl. pub. no. 56910 (21 pp.).*

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