Regioselective Formation of Hydroxy Lactams from Pyridine-2,3-dicarboximides and their Cyclodehydration to Pyrido[2',3':3,4]pyrrolo-fused Heterocyclic Systems

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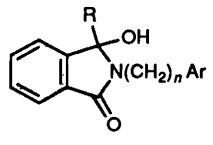
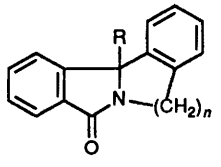
Grignard reactions of pyridine-2,3-dicarboximides involve attack at the carbonyl group closer to the pyridine nitrogen atom to give 7-hydroxypyrrolo[3,4-*b*]pyridin-5(7*H*)-one derivatives. Reduction of the same imides with sodium borohydride gives mixtures of regiosomeric hydroxy lactams, in which the 7-hydroxypyrrolo[3,4-*b*]pyridin-5-ones are the major components. Hydroxy lactams derived by either of these two methods from pyridine-2,3-dicarboximides containing *N*-benzyl, *N*-2-phenylethyl, *N*-2-(indol-3-yl)ethyl, or *N*-biphenyl-2-yl substituents are cyclised by heating in trifluoroacetic or polyphosphoric acid to give derivatives of new pyrido[2',3':3,4]pyrrolo-fused heterocyclic systems.

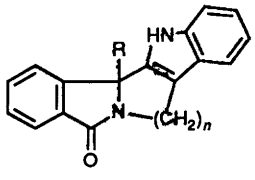
Intramolecular amidoalkylation *via* the acid-catalysed cyclodehydration of α-hydroxy lactams provides a very general procedure for the construction of fused heterocyclic systems.[1] Structures (**2**)–(**8**) are illustrative of the fused isoindole ring systems obtained in this way from *N*-substituted hydroxyphthalimidines (**1**) or, in some cases, by a double cyclisation in a single-step procedure starting from *o*-benzoylbenzoic acid and the appropriate amine.[2–4] Our aim in this work was to prepare aza analogues of the fused heterocyclic systems (**2**)–(**6**) using α-hydroxy lactams derived from pyridine-2,3-dicarboximides (**9**).[5]



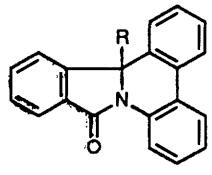
(**1**)



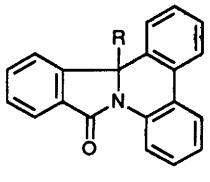
(**2**) *n* = 1, R = Ph
(**3**) *n* = 2, R = H, Ph



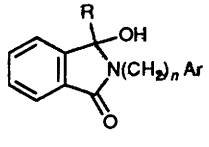
(**4**) *n* = 2, R = Ph
(**5**) *n* = 3, R = H, Me, Ph



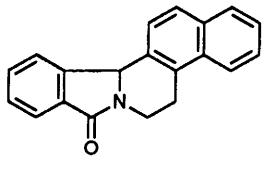
(**6**) R = H, Ph, $PhCH_2$



(**7**) R = H, Ph



a; *n* = 1, Ar = 2-thienyl
b; *n* = 1, Ar = Ph
c; *n* = 2, Ar = Ph
d, *n* = 2, Ar = indol-3-yl
e; *n* = 0, Ar = 2-PhC_6H_4
f; *n* = o, Ar = Ph



(**8**)

Results and Discussion

Sodium borohydride reduction of the imides (**9a–e**) in ethanol gave mixtures of regioisomeric α-hydroxy lactams, (**12**) and (**13**), which were separated chromatographically. The major isomer in every case was the less polar component with the higher retention factor. The yields and products isolated are listed in Table 1.

The hydroxy lactams (**12f**) and (**13f**) obtained from the imide (**9f**) were accompanied by ring-opened by-products (**10b, c**) and (**11b, c**), as has been noted previously for reductions of other *N*-aryl imides by sodium borohydride.[6] A second problem in this case was the fact that the two hydroxy lactams were inseparable by chromatography, and only the major isomer was obtained pure by fractional crystallisation. However, since (**12f**) and (**13f**) lack the potential for cyclodehydration characteristic of other members of the series, work with the imide (**9f**) was not further pursued. A cleaner reduction of the other *N*-aryl imide (**9e**) was achieved at −15 °C instead of at 0 °C, and the hydroxy lactams (**12e**) and (**13e**) were separated from each other and from unwanted by-products (**10a**) and (**11a**).

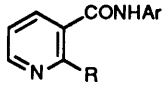
In pyridine the 2-position is more electron-deficient than the 3-position. Therefore, in the imides (**9**) the more reactive carbonyl group is expected to be that one attached to the 2-position of the pyridine ring. On this basis the major hydroxy lactam product is predicted to be the regioisomer (**12**), and we sought to confirm this by comparison of NMR spectral data in those cases where both regioisomeric products were isolable.

Resonances due to hydrogen atoms at the 2-, 3-, 4-, and 7- (or 5-) positions were identifiable in the ^1H NMR spectra of the isomeric hydroxy lactams (**12c**) and (**13c**), but chemical-shift differences were too small to permit a decision as to which compound was (**12c**) and which was (**13c**). However, irradiation of the minor isomer assigned structure (**13c**) at the frequency of the resonance for 4-H produced a nuclear Overhauser enhancement (NOE) of the resonances for 3-H and 5-H. In the same way, the major isomer assigned structure (**12c**) also showed a NOE between 4-H and 3-H, but no interaction between 4-H and 7-H.

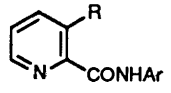
Table 1. Hydroxy lactam and fused heterocyclic products

Imide	Reagent	Hydroxy lactam(s)	% Yield	Cyclised product	% Yield
(**9a**)	$NaBH_4$	(**12a**), (**13a**)	65, 33	—	—
(**9b**)	$NaBH_4$	(**12b**), (**13b**)[a]	49, 15	—	—
(**9c**)	$NaBH_4$	(**12c**), (**13c**)[a]	56, 14	(**16a**), (**18**)	93, 55
(**9d**)	$NaBH_4$	(**12d**)[b]	56	(**17a**)	64
(**9e**)	$NaBH_4$	(**12e**), (**13e**)[c]	59, 17	(**19a**)	88
(**9f**)	$NaBH_4$	(**12f**)[b,c]	22	—	—
(**9a**)	PhMgBr	(**12g**)	78	—	—
(**9b**)	PhMgBr	(**12h**)	62	(**15**)	72
(**9c**)	PhMgBr	(**12i**)	83	(**16b**)	72
(**9d**)	PhMgBr	(**12j**)	38	(**17b**)	58
(**9e**)	PhMgBr	(**12k**)	100	(**19b**)	63
(**9e**)	MeMgI	(**12l**)	54[a]	(**19c**)	62[d]
(**9e**)	$PhCH_2MgCl$	(**12m**)	52[a]	—	—

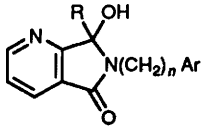
[a] Also some imide recovered. [b] Regioisomer (**13**) also present in lesser amounts, but not isolated. [c] Also ring-opened by-products. [d] Or 38% yield in two steps *via* (**20a**).



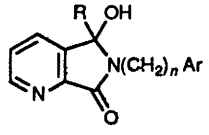
(**10**) **a**; R = CO_2Et, Ar = *o*-PhC_6H_4
b; R = CO_2Et, Ar = Ph
c; R = CH_2OH, Ar = Ph



(**11**) **a**; R = CO_2Et, Ar = *o*-PhC_6H_4
b; R = CO_2Et, Ar = Ph
c; R = CH_2OH, Ar = Ph



(**12**) **a**; *n* = 1, R = H, Ar = 2-thienyl
b; *n* = 1, R = H, Ar = Ph
c; *n* = 2, R = H, Ar = Ph
d; *n* = 2, R = H, Ar = indol-3-yl
e; *n* = 0, R = H, Ar = *o*-PhC_6H_4
f; *n* = 0, R = H, Ar = Ph
g; *n* = 1, R = Ph, Ar = 2-thienyl
h, *n* = 1, R = Ph, Ar = Ph
i; *n* = 2, R = Ph, Ar = Ph
j; *n* = 2, R = Ph, Ar = indol-3-yl
k; *n* = 0, R = Ph, Ar = *o*-PhC_6H_4
l; *n* = 0, R = Me, Ar = *o*-PhC_6H_4
m; *n* = 0, R = $PhCH_2$, Ar = *o*-PhC_6H_4



(**13**) **a**; *n* = 1, R = H, Ar = 2-thienyl
b; *n* = 1, R = H, Ar = Ph
c; *n* = 2, R = H, Ar = Ph
d; *n* = 2, R = H, Ar = indol-3-yl
e; *n* = 0, R = H, Ar = *o*-PhC_6H_4
f; *n* = 0, R = H, Ar = Ph

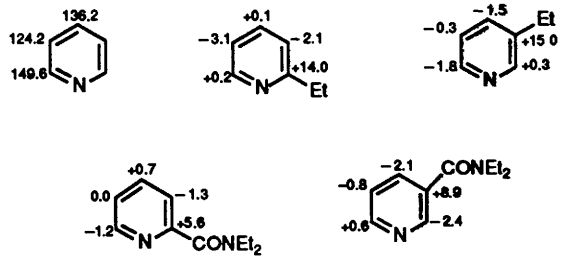
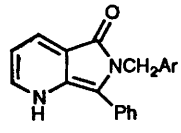


Figure. ^{13}C NMR chemical shifts for pyridine and chemical shift increments in substituted pyridines.[7,8]

Also, it was possible to assign lines in the ^{13}C NMR spectra to all except C-3 of the pyrrolo[3,4-*b*]pyridine ring system (Table 2). Significant differences were noted between pairs of regioisomers in respect of the chemical shifts of the nonprotonated carbon atoms at the 4a- and 7a-positions. In each case, the spectrum of the major isomer showed these two resonances close to 125 and 164 ppm, respectively, whereas in the spectrum of the minor isomer they were at 139 and 150 ppm, respectively.

In order to interpret these differences, we predicted chemical shifts for the pyrrolo[3,4-*b*]pyridine ring carbon atoms in structures (**12**) and (**13**) by summation of chemical-shift increments reported for pyridine bearing ethyl[7] or *N*,*N*-diethylcarbamoyl[8] substituents at either the 2- or the 3-position (see Figure). (The corresponding values for hydroxymethylpyridines were not available. The appropriateness of 2- and 3-ethylpyridines as model compounds is justified by the very similar changes in the chemical shifts of benzene ring carbon atoms induced by hydroxymethyl or ethyl substituents, respectively.[7]) The agreement between calculated and observed chemical shifts for the ring junction atoms (Table 2) confirms the assignment of structures (**12a–f**) to the major hydroxy lactam products.

Grignard reactions with the imides (**9a–e**) required the use of an excess (typically 4-fold) of the Grignard reagent for complete conversion, and better yields were obtained in reactions at low temperature (−20 or −78 °C). In each case a single adduct was obtained (**Table 1**), to which it is reasonable to assign the structures (**12g–m**) on analogy with (**12a–f**). The relevant ^{13}C NMR data for (**12g–j**) (Table 2) clearly support this assignment. For the compounds (**12e**, **k–m**) containing an *N*-biphenyl-2-yl substituent, the extra complexity of the ^{13}C NMR spectra in the region δ 120–140 ppm made assignments more difficult, and these compounds are not included in Table 2. In the mass spectra of compounds (**12g**, **h**), the highest peak at *m*/*z* 306 and 300, respectively, corresponds to loss of oxygen from the molecular ion, probably with formation of structure (**14a**, **b**). We



(**14**) **a**; Ar = 2-thienyl
b; Ar = Ph

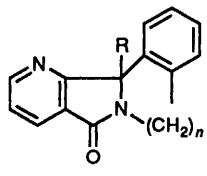
attribute the regiospecificity observed in these reactions to coordination of the pyridine nitrogen atom to the magnesium of the Grignard reagent, whereby the Grignard addition is directed to the adjacent carbonyl group (C-7). Interestingly, the presence of magnesium perchlorate has recently been shown to enhance the regioselectivity of reduction of pyridine-2,3-dicarboximides by sodium borohydride in the same sense.[9]

Cyclodehydration of the hydroxy lactams (**12c**) and (**13c**) was achieved in hot trifluoroacetic acid, whereby each gave a single product, (**16a**) and (**18**), respectively. Their ^{13}C NMR data (Table 2) are very similar to those of the corresponding

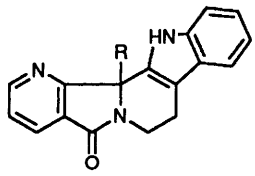
Table 2. ^{13}C NMR chemical shifts[a] of heterocyclic ring atoms

Compound	C-2	C-3	C-4	C-4a	C-5	C-7	C-7a
Predicted for (12)	150.4	120.3	134.2	131.0	168.6	—	161.2
(12a)	153.0	—[b]	131.3	124.7[c] (125.0)	164.4	80.5	163.7
(12b)	152.7	—[b]	131.1	125.0	164.6	80.7	163.8
(12c)	151.7	—[b]	132.3	124.7	165.1	81.2	163.6
(12d)	152.5	—[b]	130.8	125.4	164.5	81.1	164.0
(12f)	153.5	—[b]	131.5	124.9	164.0	82.3	163.2
(12g)	152.7	—[b]	132.2	124.7	166.6	91.4	165.5
(12h)	152.9	—[b]	132.1	124.6	166.6	91.6	165.8
(12i)	152.7	—[b]	131.9	124.9	166.6	91.3	165.7
(12j)	152.5	—[b]	131.9	124.9[c] (124.2)	166.6	91.5	166.0
(15)[d]	153.6	—[b]	132.6	125.6[c] (126.1)	168.5	79.1	171.8
(16a)[d]	152.6	—[b]	131.7	126.0	165.9	59.6	164.1
(16b)[d]	152.6	—[b]	132.0	125.3[c] (126.1)	166.0	69.7	168.1
(17a)[d]	152.4	—[b]	132.6	126.2[c] (126.6)	166.2	57.5	162.9
(17b)[d]	152.9	—[b]	132.7	125.6[c] (126.5)	165.9	67.7	167.2
Predicted for (13)	146.6	123.9	135.4	137.9	—	168.6	155.5
(13a)	151.5	—[b]	132.3	139.1[c] (139.6)	78.1	164.3	149.6
(13b)	151.4	—[b]	133.2	139.2	78.5	164.7	149.8
(13c)	151.0	—[b]	132.4	138.6[c] (139.0)	79.9	165.3	149.8
(18)[e]	151.0	—[b]	131.8	138.2	57.0	165.8	150.6

[a] Values given as δ/ppm downfield from tetramethylsilane for solutions in $^2HCCl_3$, except (12a, b, d, f) and (13b) in $(C^2H_3)_2SO$. [b] C-3 Resonance not assigned, because other aryl CH also give signals in similar position. [c] C-4a Resonance assigned to either one of those given. [d] The skeletal numbering schemes for (15)–(17) are different, but the chemical shifts are quoted for ring atoms corresponding to C(2)–C(7a) of structure (12). [e] The skeletal numbering scheme for (18) is different, but the chemical shifts are quoted for ring atoms corresponding to C(2)–C(7a) of structure (13).



(15) n = 1, R = Ph
(16) a; n = 2, R = H
b; n = 2, R = Ph



(17) a; R = H
b; R = Ph

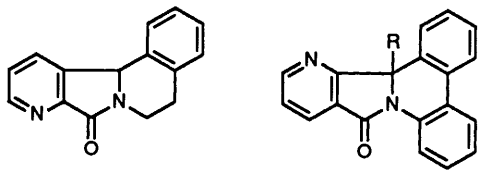
hydroxy lactams, except for an upfield shift of the hydroxylated carbon in (12c) and (13c), which becomes the new ring junction atom in (16a) and (18), respectively. The same acid treatment of other hydroxy lactams (12d, e, h–k) afforded the corresponding fused heterocyclic products shown in Table 1.

Under the same conditions, an alternative dehydration of the hydroxy lactams (12l, m) occurred to give the enamides (20a, b). ^1H NMR evidence identifies the methylene or benzylidene group in (20a, b), respectively. Precedents for this mode of dehydration have been noted before.[10] The enamide (20a) could be isomerised to (19c) by heating in polyphosphoric acid, although the same product (19c) was obtained in better yield directly from (12l) with polyphosphoric acid (Table 1). The formation of (19c) from (20a) is akin to the ring closure to give (5; R = Me),[2] which occurs on treatment of (21) with formic or hydrochloric acid.

No cyclised products were obtained by heating the hydroxy lactams (12a, b, g, h) in trifluoroacetic acid. Under more forcing conditions in hot polyphosphoric acid, (15) was obtained from (12h), but the other hydroxy lactams decomposed without giving isolable products. This difference in behaviour between the two *N*-benzyl compounds (12b) and (12h) is clearly attributable to the 7-phenyl group present in the latter. A similar difference was recorded for the related hydroxyphthalimidines (1; n = 1, Ar = Ph),[3] from which cyclised product (2) was obtained if R = Ph but not if R = H. Intramolecular amidoalkylations of this kind involve acyliminium ions as intermediates,[1] and cyclisation of an *N*-benzyliminium ion is a disfavoured *5-endo-trigonal* process with respect to the C=N bond.[11] The same is true if the *N*-substituent is 2-thienylmethyl as in (12a, g), but the cyclisation is then even less favourable, as it must result in the consecutive fusion of three five-membered rings. Not only does a phenyl group stabilise the intermediate iminium ion, but it may also facilitate ring-closure by conferring *5-exo-trigonal* character on the cyclisation step (22).[12]

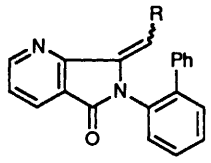
Experimental

IR spectra were recorded for Nujol mulls and calibrated with polystyrene (Pye-Unicam 1025 and SP3-200 and Perkin-Elmer 257 and 1420 spectrophotometers). ^1H NMR spectra were recorded at 60 (Varian EM360-A), 90 (JEOL-JNM-FX90Q), or 300 MHz (Bruker MSL300) and ^{13}C NMR spectra at 22.5 (MHz (JEOL-JNM-FX90Q) for solutions in ^2H chloroform (unless otherwise stated) with tetramethylsilane as internal standard. Mass spectra were obtained by electron impact at 70 eV (Kratos MS30). Preparative TLC was performed on silica-coated plates using centrifugal assistance to achieve radial separation (Chromatotron), whereby all new compounds were obtained chromatographically pure. Light petroleum refers to the fraction, b.p. 40–60 °C. Ether and tetrahydrofuran for Grignard reactions were dried before use.

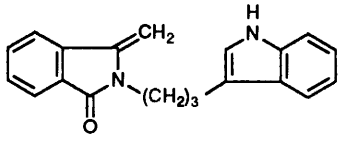


(18)

(19) **a**; R = H
b; R = Ph
c; R = Me



(20) **a**; R = H
b, R = Ph



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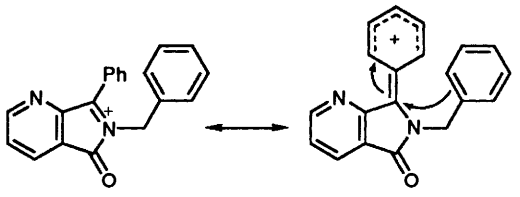

(22)

Pyridine-2,3-dicarboximides (**9a–f**).—Pyridine-2,3-dicarboxylic acid (5.0 g, 0.03 mol) was heated under reflux in acetic anhydride (100 ml) for 2 h. This mixture was then evaporated to dryness. The appropriate amine (0.03 mol) dissolved in tetrahydrofuran (100 ml) was added to the residue of pyridine-2,3-dicarboxylic anhydride and heated under reflux for 2 h. The mixture was again evaporated to dryness, and the crude amido acid redissolved in acetic anhydride (100 ml) and heated under reflux for 2 h; it was then cooled and poured into ice–water. The precipitated imide was collected and recrystallised from ethanol. The N-(*2-thienylmethyl*)*imide* (**9a**), m.p. 150–152 °C (Found: M^+, 244.0305. $C_{12}H_8N_2O_2S$ requires M^+, 244.0306); ν_{max} 1 785w and 1 725s cm^{-1} (C=O); *m/z* 244 (M^+, 45%), 216 (15), 187 (35), 161 (15), 110 (18), 97 (78), 79 (100), and 77 (89). *N*-Benzyl imide (**9b**), m.p. 167–168 °C (lit.,[13] m.p. 165–167 °C), and *N*-2-phenylethyl imide (**9c**), m.p. 137–139 °C (lit.,[13] m.p. 140–141 °C). The N-2-(*indol-3-yl*)*ethyl imide* (**9d**), m.p. 239–245 °C (decomp.) (Found: M^+, 291.099 95. $C_{17}H_{13}N_3O_2$ requires M^+, 291.1007); ν_{max} 3 220 (NH), 1 780w and 1 720s cm^{-1} (C=O); *m/z* 291 (M^+, 25%), 143 (28) and 130 (100). The N-*biphenyl-2-yl imide* (**9e**), m.p. 176–178 °C (Found: M^+, 300.0892. $C_{19}H_{12}N_2O_2$ requires M^+, 300.0892); ν_{max} 1 725s cm^{-1} (C=O); *m/z* 300 (M^+, 100%), 283 (25), 271 (55), 255 (28), and 77 (29). *N*-Phenyl imide (**9f**), m.p. 212–213 °C (lit.,[14] m.p. 215–216 °C).

Reduction of the Imides (**9a–f**).—Sodium borohydride was added in one portion to a stirred solution of the imide in ethanol maintained at the required temperature. After the time stated, the mixture was poured into saturated aqueous sodium hydrogen carbonate and extracted with chloroform. The organic extract was dried ($MgSO_4$), filtered, and evaporated to dryness. The residue was chromatographed using the solvent(s) stated to give the following products.

Imide (**9a**) (100 mg) and sodium borohydride (110 mg) in ethanol (100 ml) at 0 °C for 2.5 h. Elution with ether followed by ethyl acetate. 6,7-*Dihydro-7-hydroxy-6-(2-thienylmethyl)-pyrrolo*[3,4-b]*pyridin-5-one* (**12a**) (66 mg), m.p. 213–214 °C (from ethanol) (Found: M^+, 246.0463. $C_{12}H_8N_2O_2S$ requires M^+, 246.046 25); ν_{max} 1 660 cm^{-1} (C=O); $\delta_H[(C^2H_3)_2SO]$ 4.64 and 5.10 (each 1 H, d, *J* 15.3 Hz, CH_2), 5.71 (1 H, d, *J* 7.8 Hz, 7-H), 6.95–7.20 (3 H, m, OH and thienyl 3′-H, 5′-H), 7.45 (1 H, dd, *J* 5.1 and 1.3 Hz, thienyl 4′-H), 7.58 (1 H, dd, *J* 7.6 and 5.1 Hz, 3-H), 8.14 (1 H, dd, *J* 7.6 and 1.7 Hz, 4-H), and 8.79 (1 H, dd, *J* 5.1 and 1.7 Hz, 2-H); *m/z* 246 (M^+, 6%), 217 (5), 112 (100), 97 (33), and 79 (32). The regioisomeric *hydroxy lactam* (**13a**) (34 mg), m.p. 203–204 °C (decomp.) (from ethanol) (Found: M^+, 246.0462. $C_{12}H_8N_2O_2S$ requires M^+, 246.0462); ν_{max} 1 715 cm^{-1} (C=O); δ_H 4.61 and 5.09 (each 1 H, d, *J* 15.2 Hz, CH_2), 5.80 (1 H, d, *J* 8.4 Hz, 7-H), 6.90–7.20 (3 H, m, OH and thienyl 3′-H, 5′-H), 7.44 (1 H, dd, *J* 5.1 and 1.3 Hz, thienyl 4′-H), 7.61 (1 H, dd, *J* 7.6 and 5.1 Hz, 3-H), 8.06 (1 H, dd, *J* 7.6 and 1.3 Hz, 4-H), and 8.77 (1 H, dd, *J* 5.1 and 1.3 Hz, 2-H); *m/z* 246 (M^+, 15%), 112 (100), 97 (56), and 78 (45).

Imide (**9b**) (200 mg) and sodium borohydride (190 mg) in ethanol (70 ml) at 0 °C for 1.2 h. Elution with ether followed by ethyl acetate returned unchanged (**9b**) (47 mg), then 6-*benzyl-6,7-dihydro-7-hydroxypyrrolo*[3,4-b]*pyridin-5-one* (**12b**) (100 mg), m.p. 198–199 °C (from ethanol) (Found: M^+, 240.0901. $C_{14}H_{12}N_2O_2$ requires M^+, 240.0899); ν_{max} 3 160 (OH) and 1 660 cm^{-1} (C=O); $\delta_H[(C^2H_3)_2SO]$ 4.42 and 4.99 (each 1 H, d, *J* 16.4 Hz, CH_2), 5.68 (1 H, d, *J* 8.3 Hz, 7-H), 7.01 (1 H, d, *J* 8.3 Hz, OH), 7.36 (5 H, s, phenyl), 7.58 (1 H, dd, *J* 7.6 and 5.1 Hz, 3-H), 7.14 (1 H, dd, *J* 7.6 and 1.3 Hz, 4-H), and 8.79 (1 H, dd, *J* 5.1 and 1.3 Hz, 2-H); *m/z* 240 (M^+, 3%), 211 (6), 106 (100), and 91 (22). The regioisomeric *hydroxy lactam* (**13b**) (30 mg), m.p. 203–207 °C (from ethanol) (Found: M^+, 240.0920. $C_{14}H_{12}N_2O_2$ requires M^+, 240.0899); ν_{max} 3 210 (OH) and 1 680 cm^{-1} (C=O); $\delta_H[(C^2H_3)_2SO]$ 4.40 and 4.97 (each 1 H, d, *J* 15.4 Hz, CH_2), 5.76 (1 H, d, *J* 9 Hz, 5-H), 6.94 (1 H, d, *J* 9 Hz, OH), 7.34 (5 H, s, phenyl), 7.61 (1 H, dd, *J* 7.7 and 5.1 Hz, 3-H), 8.04 (1 H, dd, *J* 7.7 and 1.5 Hz, 4-H), and 8.77 (1 H, dd, *J* 5.1 and 1.5 Hz, 2-H); *m/z* 240 (M^+, 19%), 149 (22), 106 (100), 91 (28), and 79 (25).

Imide (**9c**) (400 mg) and sodium borohydride (300 mg) in ethanol (100 ml) at 0 °C for 4 h. Elution with ether followed by ethyl acetate returned unchanged (**9c**) (47 mg), then 6,7-*dihydro-7-hydroxy-6-(2-phenylethyl)pyrrolo*[3,4-b]*pyridin-5-one* (**12c**) (232 mg), m.p. 136.5–137.5 °C (from ethanol) (Found: M^+, 254.1055. $C_{15}H_{14}N_2O_2$ requires M^+, 254.1055); ν_{max} 1 680 cm^{-1} (C=O); δ_H 3.01 (2 H, t, *J* 7.6 Hz, CH_2Ph), 3.89 (2 H, m, CH_2N), 5.70 (1 H, s, 7-H), 6.49 (1 H, s, OH), 7.19 (5 H, s, phenyl), 7.41 (1 H, dd, *J* 7.6 and 4.7 Hz, 3-H), 8.08 (1 H, d, *J* 7.6 Hz, 4-H), and 8.57 (1 H, d, *J* 4.7 Hz, 2-H); *m/z* 254 (M^+, 52%), 163 ($M - CH_2Ph$, 100), 136 (25), 104 (245), 91 (33), and 76 (64). The regioisomeric *hydroxy lactam* (**13c**) (55 mg), m.p. 158.5–160 °C (from ethanol) (Found: M^+, 254.1054. $C_{15}H_{14}N_2O_2$ requires M^+, 254.1055); ν_{max} 3 395 (OH) and 1 685 cm^{-1} (C=O); δ_H 3.13 (2 H, t, *J* 6.7 Hz, CH_2Ph), 3.95 (2 H, m, CH_2N), 5.56 br (1 H, s, OH), 5.98 (1 H, s, 5-H), 7.34 (5 H, s, phenyl), 7.52 (1 H, dd, *J* 7.5 and 4.7 Hz, 3-H), 8.10 (1 H, d, *J* 7.5 Hz, 4-H), and 8.69 (1 H, d, *J* 4.7 Hz, 2-H); *m/z* 254 (M^+, 50%), 163 ($M - CH_2Ph$, 52), 134 (78), 119 (42), 106 (50), 104 (100), and 78 (55).

Imide (**9d**) (200 mg) and sodium borohydride (134 mg) in ethanol (70 ml) at 20 °C for 2.5 h. Elution with ether followed by ethyl acetate. 6,7-*Dihydro-7-hydroxy-6-[2-(indol-3-yl)ethyl]-pyrrolo*[3,4-b]*pyridin-5-one* (**12d**) (112 mg), m.p. 190—192 °C

(from toluene) (Found: M^+, 293.1167. $C_{17}H_{15}N_3O_2$ requires M^+, 293.1164); ν_{max} 3 200w, br (OH) and 1 685s cm^{-1} (C=O); $\delta_H[(C^2H_3)_2SO]$ 2.90–3.20 and 3.50–4.15 (each 2 H, m, CH_2), 5.70 (1 H, d, *J* 9.5 Hz, 7-H), 6.80–7.70 (7 H, m, ArH and OH), 8.09 (1 H, dd, *J* 7.5 and 1.5 Hz, 4-H), 8.87 (1 H, dd, *J* 4.5 and 1.5 Hz, 2-H), and 10.86 (1 H, s, NH); *m/z* 293 (M^+, 25%), 275 (29), 143 (90), and 130 (100). A second fraction was unidentified solid (74 mg), possibly containing (**13d**).

Imide (**9e**) (200 mg) and sodium borohydride (250 mg) in ethanol (75 ml) at −15 °C for 1.8 h. Elution with chloroform–ethyl acetate (1:1, v/v) gave a mixture of the amido esters (**10a**) and (**11a**) (52 mg), followed by 6-*biphenyl*-2-*yl*-6,7-*dihydro*-7-*hydroxypyrrolo*[3,4-b]*pyridin*-5-*one* (**12e**) (118 mg), m.p. 333–336 °C (from ethanol) (Found: M^+, 302.1038. $C_{19}H_{14}N_2O_2$ requires M^+, 302.1055); ν_{max} 3360w (OH) and 1 690 cm^{-1} (C=O); $\delta_H(C^2H_3O^2H)$ 5.50br (1 H, s, 7-H), 7.08br (1 H, s, OH), 7.25–7.70 (10 H, m, ArH), 8.13 (1 H, dd, *J* 7.6 and 1.3 Hz, 4-H), and 8.82 (1 H, dd, *J* 5.1 and 1.3 Hz, 2-H); *m/z* 302 (M^+, 32%), 273 (10), 106 (24), and 79 (100). The regioisomeric *hydroxy lactam* (**13e**) (34 mg), oil (Found: M^+, 302.1051. $C_{19}H_{14}N_2O_2$ requires M^+, 302.1055); ν_{max} 3 160–3 355w (OH) and 1 715s cm^{-1} (C=O); $\delta_H[(C^2H_3)_2SO]$ 5.63br (1 H, s, 5-H), 5.69br (1 H, s, OH), 7.20–7.70 (10 H, m, ArH), 8.01 (1 H, dd, *J* 7.6 and 1.3 Hz, 4-H), and 8.77br (1 H, d, *J* 3.8 Hz, 2-H); *m/z* 302 (M^+, 100%), 273 (50), 197 (25), 167 (25), and 79 (50).

Imide (**9f**) (58 mg) and sodium borohydride (200 mg) in ethanol (75 ml) at 0 °C for 2 h. Elution with ether gave the amido ester (**10b**) and/or (**11b**) (11 mg); *m/z* 270 (M^+, 20%), 228 (45), 178 (18), 150 (41), 135 (99), 108 (46), 107 (65), 106 (49), 95 (70), and 93 (100); followed by a mixture of the hydroxy lactams (**12f**) and (**13f**) (16 mg), from which the major isomer, 6,7-*dihydro*-7-*hydroxy*-6-*phenylpyrrolo*[3,4-b]*pyridin*-5-*one* (**12f**) was separated by fractional crystallisation, m.p. 214–216 °C (from ethanol) (Found: M^+, 226.0748. $C_{13}H_{10}N_2O_2$ requires M^+, 226.0742); ν_{max} 3 150w, br (OH) and 1 700s cm^{-1} (C=O); $\delta_H[(C^2H_3)_2SO]$ 6.50 (1 H, d, *J* 9.7 Hz, 7-H), 7.06 (1 H, d, *J* 9.7 Hz, OH), 7.20–7.90 (6 H, m, ArH), 8.17 (1 H, dd, *J* 7.6 and 1.5 Hz, 4-H), and 8.87 (1 H, dd, *J* 3.9 and 1.5 Hz, 2-H); *m/z* 226 (M^+ 226, 32%), 198 (15), 197 (25), 106 (36), and 79 (100). A third fraction was the (hydroxymethyl)pyridinecarbanilide (**10c**) and/or (**11c**) (7 mg); *m/z* 228 (M^+, 15%), 210 (12), 181 (14), 135 (75), 108 (30), 107 (48), 106 (39), 94 (40), 93 (100), 91 (38), 80 (35), 79 (48), 78 (53), and 77 (32).

Grignard Reactions with the Imides (**9a–e**).—The Grignard reagent was freshly prepared from the appropriate halide and the stoicheiometric quantity of magnesium in ether (5 ml) by heating under reflux for 1 h. The appropriate imide was dissolved in the minimum quantity of tetrahydrofuran and added to the solution of the Grignard reagent maintained at the required temperature and stirred. After the time stated, the mixture was poured into saturated aqueous ammonium chloride and extracted with chloroform; the organic extract was dried ($MgSO_4$), filtered, and evaporated to dryness. The residue was purified by preparative TLC using the solvent stated to give the following products.

Grignard reagent from bromobenzene (325 mg) and magnesium (50 mg) with imide (**9a**) (100 mg) at −20 °C for 5 h. Elution with ether gave 6,7-*dihydro*-7-*hydroxy*-7-*phenyl*-6-(2-*thienylmethyl*)*pyrrolo*[3,4-b]*pyridin*-5-*one* (**12g**) (103 mg), m.p. 173–174 °C (from toluene–light petroleum) (Found: C, 66.6; H, 4.3; N, 8.7%; $[M - 16]^+$, 306.0826. $C_{18}H_{14}N_2O_2S$ requires C, 67.0; H, 4.4; N, 8.7%. $C_{18}H_{14}N_2OS$ requires 306.0827); ν_{max} 3 240w, br (OH); δ_H 4.41 and 4.90 (each 1 H, d, *J* 15.2 Hz, CH_2), 6.70–6.80 and 7.04–7.50 (10 H, m, OH and ArH), 8.02 (1 H, dd, *J* 7.6 and 1.3 Hz, 4-H), and 8.30 (1 H, dd, *J* 5.1 and 1.3 Hz, 2-H); *m/z* M^+ absent, 306 (M − 16, 8%), 211 (23), 182 (12), 155 (14), 154 (13), 112 (100), and 69 (36).

Grignard reagent from bromobenzene (520 mg) and magnesium (82 mg) with imide (**9b**) (200 mg) at −20 °C for 5 h. Elution with ether gave 6-*benzyl*-6,7-*dihydro*-7-*hydroxy*-7-*phenylpyrrolo*[3,4-b]*pyridin*-5-*one* (**12h**) (163 mg), m.p. 189.5–190 °C (from toluene–light petroleum) (Found: C, 75.5; H, 5.4; N, 8.8%; $[M - 16]^+$, 300.1253. $C_{20}H_{16}N_2O_2$ requires C, 75.9; H, 5.1; N, 8.9%. $C_{20}H_{16}N_2O$ requires 300.1263); ν_{max} 3 250 (OH) and 1 688 cm^{-1} (C=O); δ_H 4.20 and 4.82 (each 1 H, d, *J* 14.5 Hz, CH_2), 7.10–7.45 (10 H, m, ArH), 8.09 (1 H, dd, *J* 7.6 and 1.7 Hz, 4-H), and 8.42 (1 H, dd, *J* 5.1 and 1.7 Hz, 2-H); *m/z* M^+ absent, 300 (M − 16, 3%), 211 (35) 106 (100), and 91 (32).

Grignard reagent from bromobenzene (500 mg) and magnesium (77 mg) with imide (**9c**) (200 mg) at −20 °C for 4.5 h. Elution with ether 6,7-*dihydro*-7-*hydroxy*-7-*phenyl*-6-(2-*phenylethyl*)*pyrrolo*[3,4-b]*pyridin*-5-*one* (**12i**) (218 mg), m.p. 154.5–155.5 °C (from toluene) (Found: M^+, 330.1355. $C_{21}H_{18}N_2O_2$ requires M^+, 330.1368); ν_{max} 3 150–3 390 (OH) and 1 695 cm^{-1} (C=O); δ_H 2.53–3.94 (4 H, m, 2 × CH_2). 4.60br (1 H, s, OH), 7.00–7.50 (11 H, m, ArH), 8.00 (1 H, dd, *J* 7.6 and 1.7 Hz, 4-H), and 8.38 (1 H, dd, *J* 5.1 and 1.7 Hz, 2-H); *m/z* 330 (M^+, 4%), 239 (M − CH_2Ph, 12), 223 (13), 210 (100), 154 (19), 104 (25), 91 (25), and 77 (24).

Grignard reagent from bromobenzene (540 mg) and magnesium (70 mg) with imide (**9d**) (200 mg) at room temperature for 4 h. Elution with ethyl acetate–chloroform (1:4, v/v) followed by ether gave 6,7-*dihydro*-7-*hydroxy*-6-[2-(*indol*-3-*yl*)*ethyl*]-7-*phenylpyrrolo*[3,5-b]*pyridin*-5-*one* (**12j**) (97 mg), m.p. 96–99 °C (from toluene) (Found: M^+, 369.1477. $C_{23}H_{19}N_3O_2$ requires M^+, 369.1477); ν_{max} 3 150–3 450 (NH and OH) and 1 675 cm^{-1} (C=O); δ_H 2.83–3.42 (4 H, m, 2 × CH_2), 6.98–7.60 (11 H, m, ArH), 8.20 (1 H, dd, *J* 7.6 and 1.7 Hz, 4-H), 8.71 (1 H, dd, *J* 5.1 and 1.7 Hz, 2-H), and 8.99 (1 H, s, NH); *m/z* 369 (M^+, 14%), 351 (10), 274 (12), 210 (17), 143 (100), and 130 (48).

Grignard reagent from bromobenzene (160 mg) and magnesium (25 mg) with imide (**9e**) (200 mg) at −78 °C for 5 h. Elution with chloroform–ethyl acetate (5:1, v/v) gave 6-(*biphenyl*-2-*yl*)-6,7-*dihydro*-7-*hydroxy*-7-*phenylpyrrolo*[3,4-b]-*pyridin*-5-*one* (**12k**) (362 mg), m.p. 174–175 °C (from acetone) (Found: M^+, 378.1367. $C_{25}H_{18}N_2O_2$ requires M^+, 378.1368); ν_{max} 3 300 (OH) and 1 680 cm^{-1} (C=O); $\delta_H[(C^2H_3)_2CO]$ 6.30–7.92 (16 H, m, ArH and OH), 8.29 (1 H, dd, *J* 7.6 and 1.3 Hz, 4-H), and 8.69 (1 H, dd, *J* 5.0 and 1.3 Hz, 2-H); *m/z* 378 (M^+, 20%), 210 (100), and 154 (14).

Grignard reagent from methyl iodide (145 mg) and magnesium (25 mg) with imide (**9e**) (200 mg) at −78 °C for 4 h. Ethyl acetate–chloroform (1:2, v/v) eluted first unchanged (**9e**) (91 mg), then 6-(*biphenyl*-2-*yl*)-6,7-*dihydro*-7-*hydroxy*-7-*methylpyrrolo*[3,4-b]*pyridin*-5-*one* (**12l**) (114 mg), m.p. 209–211 °C (from toluene) (Found: M^+, 316.1214. $C_{20}H_{16}N_2O_2$ requires M^+, 316.1212); ν_{max} 3 185w, br (OH) and 1 705 cm^{-1} (C=O); δ_H 1.00 (3 H, s, CH_3), 7.16–7.75 (10 H, m, ArH and OH), 8.20 (1 H, dd, *J* 7.6 and 1.7 Hz, 4-H), and 8.72 (1 H, dd, *J* 5.1 and 1.7 Hz, 2-H); *m/z* 316 (M^+, 37%), 298 (6), 170 (50), 169 (68), 148 (100), 92 (16), and 79 (37).

Grignard reagent from benzyl chloride (105 mg) and magnesium (20 mg) with imide (**9e**) (200 mg) at −78 °C for 2 h. Elution with ether gave unchanged (**9e**) (11 mg), followed by7-*benzyl*-6-(*biphenyl*-2-*yl*)-6,7-*dihydro*-7-*hydroxypyrrolo*[3,4-b]-*pyridin*-5-*one* (**12m**) (137 mg), m.p. 84–87 °C (from toluene–light petroleum) (Found: M^+, 392.1534. $C_{26}H_{20}N_2O_2$ requires M^+, 392.1525); ν_{max} 3 050–3 250 (OH) and 1 665 cm^{-1} (C=O); ^1H NMR spectrum complicated by restricted rotation of *o*-biphenylyl group: δ_H 2.15 and 2.99 (two d, *J* 12.7 Hz) and 3.08 and 3.52 (two d, *J* 13.9 Hz, CH_2), 2.67 and 4.96 (two s, OH), 6.60–7.60 (10 H, m, ArH), 7.95 (1 H, d, *J* 7.6 Hz, 4-H), and 8.31 (1 H, d, *J* 5.1 Hz, 2-H); *m/z* 392 (M^+, 1%), 374 (1), 301 (M − CH_2Ph, 100), 283 (42), 257 (18), 169 (29), 167 (31), and 91 (50).

Cyclisations in Trifluoroacetic Acid.—The hydroxy lactam was dissolved in trifluoroacetic acid (4 ml) and heated under reflux for the time stated, after which the solution was cooled, poured into saturated aqueous sodium hydrogen carbonate, and the mixture extracted with chloroform. The extract was dried ($MgSO_4$) and evaporated to dryness and the residue was purified by preparative TLC using the solvent stated to obtain the cyclised products (**16**)–(**19**).

Hydroxy lactam (**12c**) (93 mg) heated for 3 h. Chloroform–ethyl acetate (1:1, v/v) eluted 5,12b-*dihydropyrido*[2′,3′:3,4]-*pyrrolo*[2,1-a]*isoquinolin*-8(6H)-*one* (**16a**) (80 mg), m.p. 128–130 °C (from toluene–light petroleum) (Found: $[M - 1]^+$, 235.0873. $C_{15}H_{11}N_2O$ requires 235.0871); ν_{max} 1 710 cm^{-1} (C=O); δ_H 2.75–3.80 (3 H, m) and 4.32–4.72 (1 H, m, 2 × CH_2), 5.64 (1 H, s, 12b-H), 7.10–7.50 (5 H, m, ArH), 8.11 (1 H, dd, *J* 8.9 and 1.8 Hz, 9-H), and 8.88 (1 H, dd, *J* 5.0 and 1.8 Hz, 11-H); *m/z* 236 (M^+, 100%), 235 (42), 208 (35), 207 (60), 180 (37), 152 (22), 130 (20), 103 (36), 78 (45), 77 (95), and 76 (45).

Hydroxy lactam (**12d**) (50 mg) heated for 3 h. Chloroform–ethyl acetate (1:1, v/v) eluted, 8,13b-*dihydropyrido*[2′,3′:3,4]-*pyrrolo*[2,1-a]-β-*carbolin*-5(7H)-*one* (**17a**) (30 mg), m.p. 153–158 °C (decomp.) (from toluene–light petroleum) (Found: $[M - 1]^+$, 274.0977. $C_{17}H_{12}N_3O$ requires 274.0980); ν_{max} 1 700 cm^{-1} (C=O); δ_H 2.70–3.08 (2 H, m, CH_2), 3.19–3.66 and 4.75–5.02 (each 1 H, m, CH_2N), 5.79 (1 H, s, 13*b*-H), 6.95–7.60 (5 H, m, ArH), 8.15 (1 H, dd, *J* 7.6 and 1.8 Hz, 4-H), 8.72 (1 H, dd, *J* 5.1 and 1.8 Hz, 2-H), and 8.93 (1 H, s, NH); *m/z* 275 (M^+, 100%), 274 (72), 260 (11), 247 (15), 246 (25), 29 (15), 218 (18), and 190 (8).

Hydroxy lactam (**12e**) (113 mg) heated for 4.5 h. Chloroform eluted *pyrido*[2′,3′:3,4]*pyrrolo*[1,2-f]*phenanthridin*-13(8bH)-*one* (**19a**) (84 mg), m.p. 165–167 °C (from ethanol) (Found: C, 79.8; H, 4.3; N, 9.9%; $[M - 1]^+$, 283.0869. $C_{19}H_{12}N_2O$ requires C, 80.2; H, 4.3; N, 9.9%. $C_{19}H_{11}N_2O$ requires 283.0871); ν_{max} 1 720 cm^{-1} (C=O); δ_H 5.89 (1 H, s, 8*b*-H), 7.17–7.69, 7.80–8.01, and 8.10–8.44 (10 H, m, ArH), and 8.90 (1 H, dd, *J* 5.1 and 1.7 Hz, 10-H); *m/z* 284 (M^+, 88%), 283 (100), 256 (33), 255 (72), 227 (12), 177 (11), 151 (14), and 77 (22).

Hydroxy lactam (**12i**) (60 mg) heated for 3 h. Ether eluted 5,12b-*dihydro*-12b-*phenylpyrido*[2′,3′:3,4]*pyrrolo*[2,1-a]*isoquinolin*-8(6H)-*one* (**16b**) (41 mg), m.p. 185–186.5 °C (from toluene–light petroleum) (Found: C, 80.6; H, 5.2; N, 9.0. $C_{21}H_{16}N_2O$ requires C, 80.8; H, 5.2; N, 9.0%); ν_{max} 1 695 cm^{-1} (C=O); δ_H 2.60–3.60 and 4.20–4.52 (4 H, m, 2 × CH_2), 6.94–7.47 (9 H, m, ArH), 8.18 (1 H, dd, *J* 7.6 and 1.5 Hz, 9-H), 8.15–8.31 (1 H, m, 10-H), and 8.85 (1 H, dd, *J* 5.1 and 1.5 Hz, 11-H); *m/z* 312 (M^+, 8%) and 235 (M − Ph, 100).

Hydroxy lactam (**12j**) (100 mg) heated for 3.5 h. Chloroform–ethyl acetate (4:1, v/v) eluted 8,13b-*dihydro*-13b-*phenylpyrido*-[2′,3′:3,4]*pyrrolo*[2,1-a]-β-*carbolin*-5(7H)-*one* (**17b**) (55 mg), m.p. 153–158 °C (decomp.) (from ethanol) (Found: M^+, 351.1365. $C_{23}H_{12}N_3O$ requires M^+, 351.1372); ν_{max} 3 100–3 400w (NH) and 1 700s cm^{-1} (C=O); δ_H 2.80–3.40 (3 H, m) and 4.54–4.83 (1 H, m, 2 × CH_2), 6.98–7.60 (10 H, m, ArH), 8.21 (1 H, dd, *J* 7.6 and 1.7 Hz, 4-H), 8.70 (1 H, dd, *J* 5.1 and 1.7 Hz, 2-H), and 9.01 (1 H, s, NH); *m/z* 351 (M^+, 48%), 275 (19), 274 (100), and 77 (41).

Hydroxy lactam (**12k**) (197 mg) heated for 3 h. Chloroform eluted 8b-*phenylpyrido*[2′,3′:3,4]*pyrrolo*[1,2-f]*phenanthridin*-13(8bH)-*one* (**19b**) (119 mg), m.p. 259–260 °C (from ethanol) (Found: M^+, 360.1261. $C_{25}H_{16}N_2O$ requires M^+, 360.1262); ν_{max} 1 715 cm^{-1} (C=O); δ_H 7.04–7.58 (10 H, m, ArH), 7.71–7.91 and 8.11–8.30 (each 2 H, m, ArH), 8.44–8.58 (1 H, m, 12-H), and 8.82 (1 H, dd, *J* 5.1 and 1.7 Hz, 10-H); *m/z* 360 (M^+, 18%) and 283 (M − Ph, 100).

Hydroxy lactam (**12l**) (67 mg) heated for 3.5 h. Ether eluted 6-(*biphenyl*-2-*yl*)-6,7-*dihydro*-7-*methylenepyrrolo*[3,4-b]*pyridin*-5-*one* (**20a**) (51 mg, 81%), oil (Found: M^+, 298.1104. $C_{20}H_{14}N_2O$ requires M^+, 298.1106); δ_H 4.64 and 5.57 (each 1 H, d, *J* 2.3 Hz, CH_2), 7.12–7.66 (10 H, m, ArH), 8.10 (1 H, dd, *J* 8.1 and 1.8 Hz, 4-H), and 8.76 (1 H, dd, *J* 5.1 and 1.8 Hz, 2(H); *m/z* 298 (M^+, 100), 283 (40), 270 (45), 269 (60), and 166 (13). A second fraction was unchanged (**12l**) (8 mg).

Hydroxy lactam (**12m**) (71 mg) heated for 2 h. Chloroform–ethyl acetate (10 : 1, v/v) eluted 7-*benzylidene*-6-(*biphenyl*-2-*yl*)-6,7-*dihydropyrrolo*[3,4-b]*pyridin*-5-*one* (**20b**) (51 mg, 75%), oil (Found: $[M - 1]^+$, 373.1338. $C_{26}H_{17}N_2O$ requires 373.1341); δ_H 6.75–7.65 (15 H, m, ArH and CHPh), 7.70–7.86 (1 H, m, 3-H), 8.09–8.28 (1 H, m, 4-H), and 8.68–8.82 (1 H, m, 2-H); *m/z* 374 (M^+, 83%), 373 (100), 349 (9), and 289 (12).

Hydroxy lactam (**13c**) (80 mg) heated for 3.5 h. Chloroform–ethyl acetate (1:1, v/v) eluted 5,12b-*dihydropyrido*[3′,2′:3,4]-*pyrrolo*[2,1-a]*isoquinolin*-8(6H)-*one* (**18**) (41 mg), m.p. 200–202 °C (decomp.) (from toluene–light petroleum) (Found: $[M - 1]^+$, 235.0873. $C_{15}H_{11}N_2O$ requires 235.0871); ν_{max} 1 700 cm^{-1} (C=O); δ_H 2.70–3.20 (2 H, m, CH_2), 3.35–3.67 and 4.35–4.66 (each 1 H, m, CH_2N), 5.70 (1 H, s, 12a-H), 7.12–7.62 (5 H, m, ArH), 8.27 (1 H, dd, *J* 7.6 and 1.2 Hz, 12-H), and 8.86 (1 H, m, ArH), 8.27 (1 H, dd, *J* 7.6 and 1.2 Hz, 12-H), and 8.86 (1 H, dd, *J* 5.1 and 1.2 Hz, 10-H); *m/z* 236 (M^+, 100%), 235 (98), 207 (30), 180 (15), and 149 (12).

Cyclisations in Polyphosphoric Acid.—The requisite compound was dissolved in polyphosphoric acid (*ca.* 10 g) and heated at 150 °C for the time stated, after which the solution was cooled, stirred into ice–water, and extracted with chloroform. The extract was dried ($MgSO_4$), filtered, and evaporated to dryness. The residue was purified by preparative TLC to give the cyclised products (**15**) and (**19c**).

Hydroxy lactam (**12h**) (80 mg) heated for 1.25 h. Eluted with chloroform. 7,11b-*Dihydro*-11b-*phenylpyrido*[2′,3′:3,4]*pyrrolo*-[2,1-a]*isoindol*-5-*one* (**15**) (55 mg), m.p. 171–172 °C (from toluene–light petroleum) (Found: M^+, 298.1101. $C_{20}H_{14}N_2O$ requires M^+, 298.1106); ν_{max} 1 705 cm^{-1} (C=O); δ_H 4.52 and 5.28 (each 1 H, d, *J* 15.2 Hz, CH_2), 7.17–7.42 (9 H, m, ArH), 7.95–8.02 (1 H, m, 3-H), 8.09 (1 H, dd, *J* 7.6 and 1.3 Hz, 4-H), and 8.88 (1 H, dd, *J* 5.1 and 1.3 Hz, 2-H); *m/z* 298 (M^+, 19%), 269 (9), 221 (M − Ph, 100), 192 (8), 166 (11), 85 (29), and 83 (49).

Hydroxy lactam (**12l**) (67 mg) heated for 2 h. Eluted with chloroform. 8b-*Methylpyrido*[2′,3′–3,4]*pyrrolo*[1,2-f]*phenanthridin*-13(8bH)-*one* (**19c**) (32 mg), m.p. 176.5–178 °C (from ethanol) (Found: M^+, 298.1104. $C_{20}H_{14}N_2O$ requires M^+, 298.1106); ν_{max} 1 700 cm^{-1} (C=O); δ_H 1.68 (3 H, s, CH_3), 7.20–7.59 and 7.77–8.36 (each 5 H, m, ArH), and 8.92 (1 H, dd, *J* 5.1 and 1.7 Hz, 10-H); *m/z* 298 (M^+, 18%), 284 (21), and 283 (M − Me, 100). A second fraction was unchanged (**12l**) (2 mg). The same cyclised product (**19c**) (18 mg) was obtained from lactam (**20a**) heated for 1.25 h in polyphosphoric acid and worked up by the same procedure.

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