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NOVEL INDOLE-FUSED, MEDIUM-SIZED RING HETEROCYCLES *VIA* CHLOROACETAMIDE PHOTOCHEMISTRY

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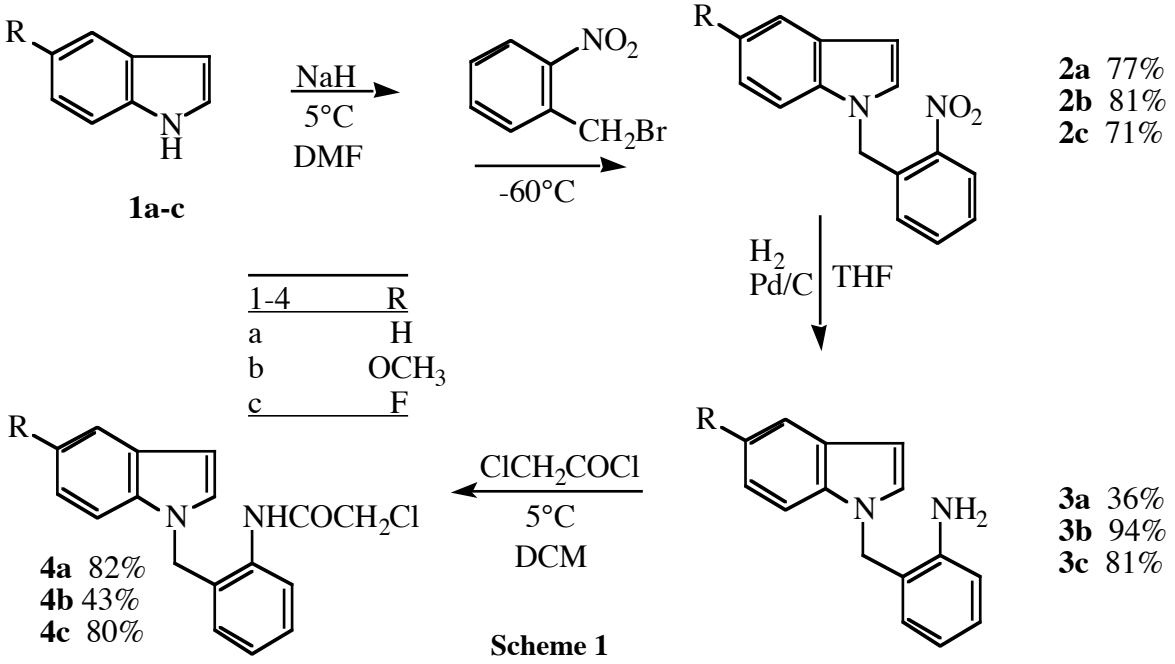
Abstract - Syntheses of derivatives of three novel indole-fused systems based on *indolo[2,1-d][1,5]benzodiazocine*, *indolo[7,7a,1-d,e][1,6]benzodiazonine* and *pyrrolo[2,3-b]indolo[5,5a,6-b,a]quinazoline*, the first two including 8- and 9-membered ring heterocycles, are described. These derivatives resulted from the photo-induced cyclization of the respective chloroacetamide precursors prepared *via* *N*-alkylation of the appropriate indole with 2-nitrobenzyl bromide, subsequent nitro group reduction and then *N*-chloroacetylation. Structural and stereochemical features of these new ring system derivatives are discussed.

The use of chloroacetamide derivatives as substrates for photocyclization is a proven method for making a variety of nitrogen heterocyclic systems, especially medium-ring lactams.[1,2] This type of cyclization has been used on a variety of indolic systems to yield not only indolobenzazepines but also indolobenzazocine and indolobenzazonine skeletons.[3-7] As part of a program to access novel fused indole structures for pharmacological screening, we have investigated new applications of this photo-induced cyclization of chloroacetamide derivatives. In particular, chloroacetamide systems linked to the 1-position of indole were targeted in an effort to access the new indolo[2,1-*d*][1,5]benzodiazocine skeleton containing an indole-fused 8-membered ring.

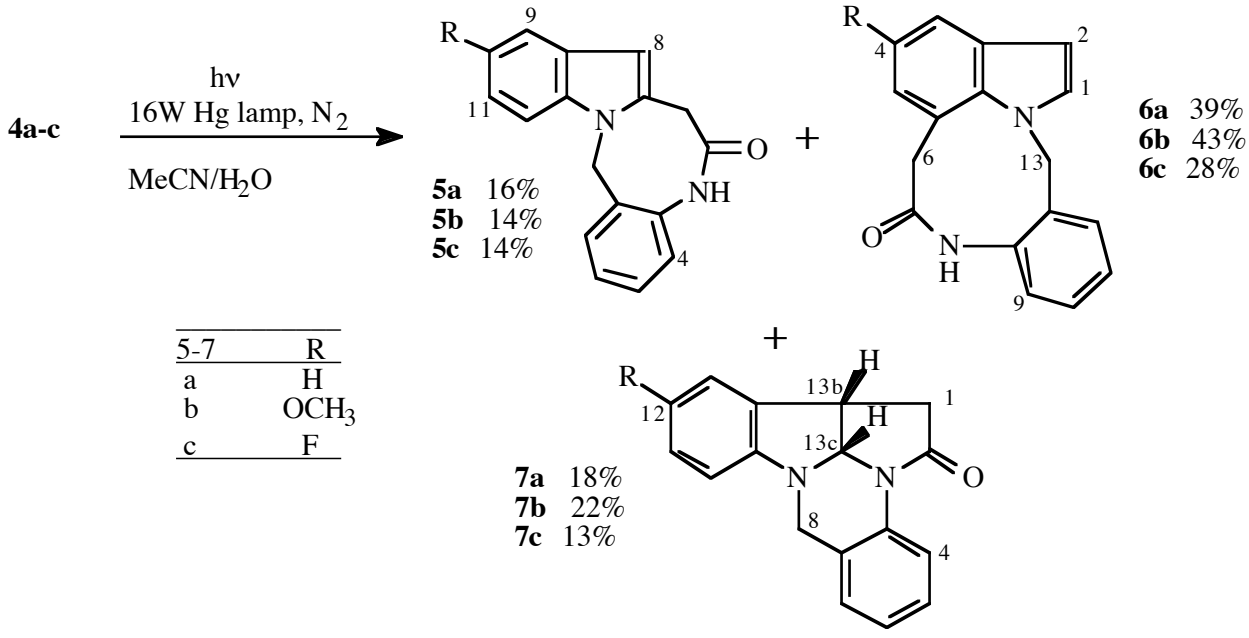
The particular precursor chloroacetamides (**4a-c**) required were prepared from the respective anilines (**3a-c**) which were accessed in turn from the indoles (**1a-c**) *via* the *N*-alkylated derivatives (**2a-c**) (Scheme 1). Initial attempts to alkylate indole (**1a**) using 2-nitrobenzyl chloride *via* several published routes[8-11] were unsuccessful yielding instead chloride self-condensation products. It is probable that this was due primarily to the acidity of the benzylic hydrogens which allowed the indole anion to act more as a base than a nucleophile. Switching to the corresponding 2-nitrobenzyl bromide and using a modification of the procedure of Ho,[12] alleviated the problem and alkylation products (**2a-c**) were obtained in reasonable yield. The subsequent reductions to **3a-c** and chloroacetylations with chloroacetyl chloride to **4a-c** were accomplished under mild conditions. The structures of the products in Scheme 1 were confirmed by NMR spectroscopic analysis and MS.

Photolysis of the chloroacetamides (**4a-c**) was conducted in 50% acetonitrile-water solution using a 16W mercury lamp (Scheme 2). As anticipated from electronic considerations consequent on photo-induced single electron transfer from the indolic moiety, **4b** reacted significantly faster than **4a** (4 hours versus 8 hours), while **4c** required at least 16 hours to complete reaction. The methoxy series gave higher yields as expected because of the stabilising effect of the electron releasing methoxy group on the intermediate indolic radical cation. The yields in the fluoro series were somewhat poorer probably due to radical cation destabilization by the fluoro atom.

Not only were the expected benzodiazocine products (**5a-c**) produced but, in addition, two other new ring systems resulted: an indolo[7,7a,1-*d,e*][1,6]benzodiazonine (**6a-c**) and a pyrrolo[2,3-*b*]indolo[5,5a,6-*b,a*]quinazoline (**7a-c**). A significant portion of the latter skeleton is a hexahydropyrrolo[2,3-*b*]indole which is shared with a range of alkaloids including the acetylcholinesterase inhibitor, physostigmine, and the securamines (plus flustramines) isolated from marine bryozoans which show interesting biological activity.[13-15]



Scheme 1



Scheme 2

Separation of the derivatives of **5**, **6** and **7** from the photosylates was accomplished by column chromatography. Derivatives (**7a-c**) had higher R_fs and eluted cleanly for all series. Derivatives of **5** and **6** had lower and very close R_fs and complete separation was more difficult, especially for **5c** and **6c**. However, enough pure material was obtained for characterization.

Yields of both **5a-c** and **6a-c** were determined based upon isolated material plus ^{1}H-NMR analysis of the residual mixtures using the clearly separated signals for the CH_2 adjacent to the carbonyl which occured around δ 3.50 as a sharp singlet; the indolic 3-proton which occured between δ 6.30 and δ 6.50 as either a singlet (**5a-c**) or a doublet (**6a-c**); and the lactam N-H proton which appeared as a broadened singlet generally below δ 8.20.

The structures of **5a-c** and **6a-c** were initially deduced from the NMR spectra which show a singlet for H-8 in the region of δ 6.50 for **5a-c**, while for **6a-c** the corresponding signal (H-2) is a doublet analogous to those for the *N*-substituted indole precursors. This signal is not present in the spectra of (**7a-c**) since these protons are now on a dihydroindolic moiety. For the fluoro analogs, *ortho* and *meta* proton-F19 (J^oH-F and J^mH-F) and F19-C13 (J^1 and J^2) couplings gave rise to more complex signals in both the proton and carbon-13 NMR spectra.

The basic structure of **7a-c** was initially determined by 2D-COSY analysis. The COSY spectrum of **7a** revealed the specific couplings of most of the protons. For the aliphatic protons the two H-1 protons (doublet at δ 2.80 and doublet of doublets at δ 3.18) showed cross peaks to each other and to the H-13b multiplet at δ 3.90; H-13b showed cross peaks not only to both protons in the 1-position but also to the H-13c doublet (δ 5.44) and at least one aromatic proton (probably H-7). The H-8 methylene protons (doublets at δ 4.63 and 4.75) correlated strongly only to each other. The aromatic protons also showed several specific correlations in two fairly distinct groupings: one between δ 6.50 to 7.20 and another from δ 7.00 to 8.20. The upfield group showed four sets of cross peaks the clearest of which were those between H-10 (doublet at δ 6.59) and H-12 (doublet of doublets of doublets at δ 6.79). The downfield group had one clear correlation between the doublet at δ 8.20 (H-4) and a doublet of doublets of doublets at δ 7.22 (H-5). The doublet at δ 8.20 in **7a** was ascribed to H-4, consistant with the deshielding effect expected from the lactam carbonyl group.

The COSY spectrum of **7b** showed identical correlations for the aliphatic protons and somewhat more detailed correlations for the aromatic region with the H-13 proton (δ 6.78) showing cross peaks to the signal at δ 6.71 for the H-11 proton. The H-10 and H-11 protons showed strong mutual cross peaks. There were also cross peaks for H-13 showing a correlation to H-13b. The H-4 proton was again obvious at δ 8.22 with clear cross peaks to the other three protons of its ring.

Structures of a representative of each structural series (**5b**, **6a** and **7a**) were confirmed unequivocally by X-Ray crystallography[16] as shown in Figures 1, 2, and 3; for each figure, 50% ellipsoids are shown for the non-hydrogen atoms, together with skeletal numbering, and hydrogen atoms have arbitrary radii of 0.1Å. Non-hydrogen atom coordinates and equivalent isotropic thermal parameters for **5b**, **6a** and **7a** are given in the corresponding Tables 1, 2 and 3; in the case of **6a**, four molecules were present in the asymmetric unit cell, and only molecule 1 is given here.[16] The study of **7a** confirmed the 13a-13b ring junction as *cis* and the overall structure correlated extremely well with the "butterfly shaped" structure predicted by molecular modelling (Merck Force Field)[17] for **7a** wherein, *in vacuo,* this compound with the *cis* ring junction has a strain energy of only 24.89 kJ/mol; the compound with the *trans* ring junction has a much higher calculated strain energy of 137.61 kJ/mol.

The mechanism leading to the cyclization products most probably involves photo-induced, single electron transfer (S.E.T.) and subsequent chloride ion loss to give a resonance stabilized intermediate which can then cyclize *via* three pathways as indicated in Figure 4.

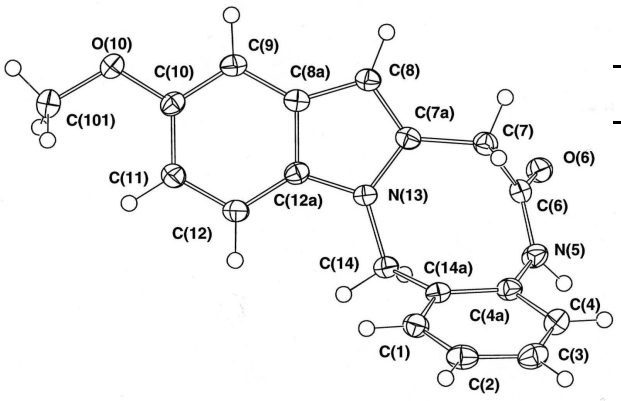


Figure 1. Molecular projection of **5b** normal to the phenyl ring.

Table 1. Non-hydrogen atom coordinates and equivalent isotropic thermal parameters of **5b**.

Atom	*x*	*y*	*z*	U_{eq} Å^2
C(1)	0.2302(2)	0.56835(6)	0.2255(1)	0.0256(7)
C(2)	0.2253(2)	0.63814(7)	0.2121(1)	0.0286(7)
C(3)	0.0522(2)	0.67080(7)	0.1638(1)	0.0298(8)
C(4)	-0.1146(2)	0.63449(6)	0.1340(1)	0.0271(7)
C(4a)	-0.1091(2)	0.56454(6)	0.1500(1)	0.0223(7)
N(5)	-0.2824(1)	0.52812(5)	0.1152(1)	0.0247(6)
C(6)	-0.3364(2)	0.48286(6)	0.1930(1)	0.0217(6)
O(6)	-0.4814(1)	0.44858(4)	0.14745(8)	0.0259(5)
C(7)	-0.2221(2)	0.47809(6)	0.3408(1)	0.0228(7)
C(7a)	-0.0703(2)	0.42516(6)	0.3770(1)	0.0207(6)
C(8)	-0.0334(2)	0.37949(6)	0.4807(1)	0.0219(7)
C(8a)	0.1388(2)	0.34489(6)	0.4850(1)	0.0206(6)
C(9)	0.2501(2)	0.29552(6)	0.5687(1)	0.0228(7)
C(10)	0.4125(2)	0.27301(6)	0.5414(1)	0.0228(7)
O(10)	0.5184(1)	0.22552(4)	0.62961(9)	0.0295(5)
C(101)	0.6847(2)	0.20013(7)	0.6042(2)	0.0314(8)
C(11)	0.4643(2)	0.29744(6)	0.4310(1)	0.0253(7)
C(12)	0.3575(2)	0.34682(6)	0.3483(1)	0.0255(7)
C(12a)	0.1978(2)	0.37115(5)	0.3777(1)	0.0210(6)
N(13)	0.0705(1)	0.42107(5)	0.3144(1)	0.0213(5)
C(14)	0.0726(2)	0.45408(6)	0.1890(1)	0.0229(7)
C(14a)	0.0639(2)	0.53031(6)	0.1916(1)	0.0215(6)

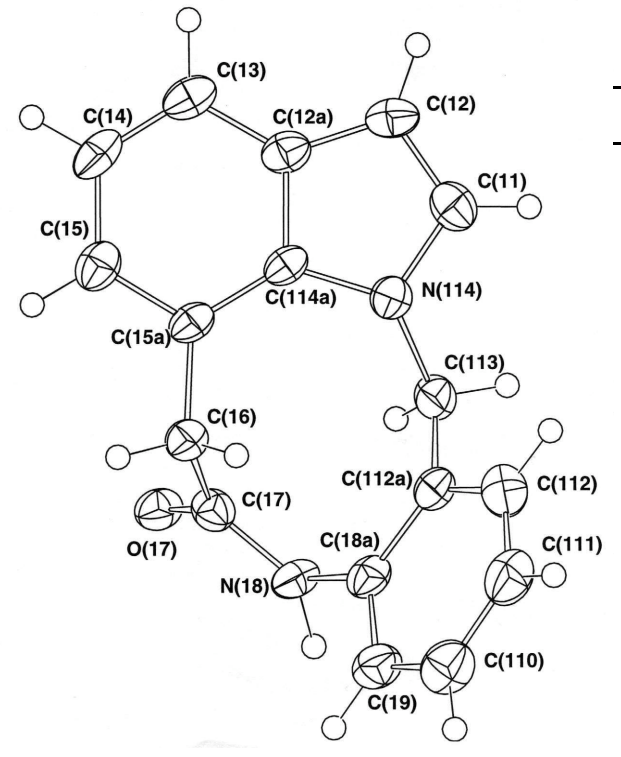


Figure 2. Molecular projection of **6a** (molecule 1) normal to the phenyl ring.

Table 2. Non-hydrogen atom coordinates and equivalent isotropic thermal parameters of **6a** (molecule 1)

Atom	*x*	*y*	*z*	U_{eq} Å^2
C(11)	-0.0240(4)	0.0901(5)	1.2353(4)	0.037(5)
C(12)	-0.0099(5)	0.0701(5)	1.3236(4)	0.036(5)
C(12a)	0.0865(4)	-0.0127(5)	1.3311(4)	0.034(5)
C(13)	0.1419(5)	-0.0659(5)	1.4043(4)	0.037(5)
C(14)	0.2369(5)	-0.1418(5)	1.3885(4)	0.039(5)
C(15)	0.2824(5)	- 0.1636(5)	1.2984(4)	0.036(5)
C(15a)	0.2310(4)	-0.1124(4)	1.2240(4)	0.029(5)
C(16)	0.2901(4)	-0.1289(4)	1.1257(4)	0.032(5)
C(17)	0.2567(4)	-0.1911(4)	1.0891(4)	0.032(5)
O(17)	0.2651(3)	-0.2832(3)	1.1300(3)	0.035(3)
N(18)	0.2226(4)	-0.1449(4)	1.0058(3)	0.032(4)
C(18a)	0.1993(4)	-0.0369(4)	0.9602(4)	0.031(5)
C(19)	0.2550(5)	-0.0084(5)	0.8684(4)	0.039(5)
C(110)	0.2354(5)	0.0964(5)	0.8216(5)	0.046(6)
C(111)	0.1593(5)	0.1710(5)	0.8679(5)	0.048(6)
C(112)	0.1006(5)	0.1421(5)	0.9574(5)	0.039(5)
C(112a)	0.1188(4)	0.0373(5)	1.0056(4)	0.032(5)
C(113)	0.0493(4)	0.0070(5)	1.1004(4)	0.037(5)
N(114)	0.0612(3)	0.0267(4)	1.1824(3)	0.032(4)
C(114a)	0.1311(4)	-0.0392(4)	1.2418(4)	0.027(4)

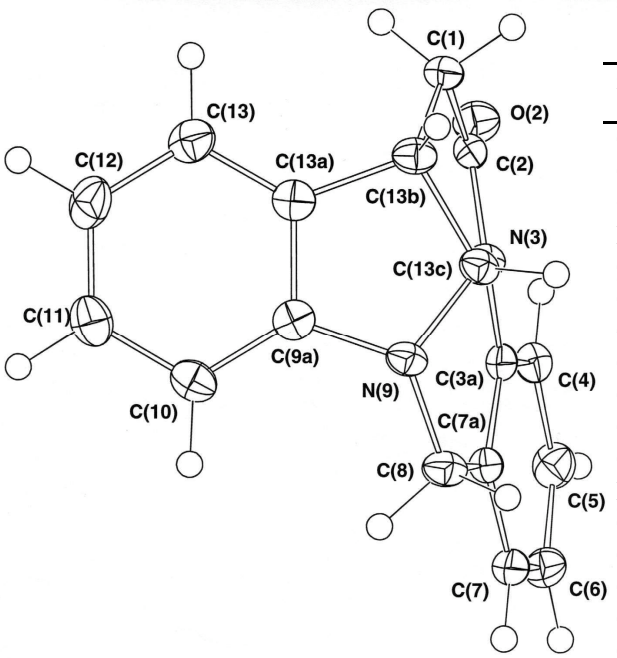


Figure 3. Molecular projection of **7a** normal to the phenyl ring

Table 3. Non-hydrogen atom coordinates and equivalent isotropic thermal parameters of **7a**.

Atom	*x*	*y*	*z*	U_{eq} Å^2
C(1)	0.3084(3)	0.4222(2)	0.2000(1)	0.0222(9)
C(2)	0.4824(3)	0.3918(1)	0.2506(1)	0.0198(8)
O(2)	0.5178(2)	0.4415(1)	0.31092(7)	0.0271(7)
N(3)	0.5937(2)	0.2987(1)	0.21659(7)	0.0190(7)
C(3a)	0.7792(3)	0.2479(2)	0.23902(9)	0.0196(8)
C(4)	0.8523(3)	0.2630(2)	0.3115(1)	0.0233(8)
C(5)	1.0304(3)	0.2055(2)	0.3316(1)	0.028(1)
C(6)	1.1339(3)	0.1310(2)	0.2812(1)	0.0276(9)
C(7)	1.0633(3)	0.1181(2)	0.2087(1)	0.0240(9)
C(7a)	0.8887(3)	0.1784(1)	0.1862(1)	0.0198(8)
C(8)	0.8210(3)	0.1659(2)	0.1057(1)	0.0239(9)
N(9)	0.6537(2)	0.2476(1)	0.08742(8)	0.0208(7)
C(9a)	0.6720(3)	0.3722(2)	0.05900(9)	0.0211(8)
C(10)	0.8217(3)	0.4231(2)	0.01514(9)	0.0255(9)
C(11)	0.7981(3)	0.5478(2)	-0.0108(1)	0.031(1)
C(12)	0.6314(4)	0.6188(2)	0.0075(1)	0.033(1)
C(13)	0.4822(3)	0.5663(2)	0.0520(1)	0.028(1)
C(13a)	0.5023(3)	0.4426(2)	0.07744(9)	0.0222(8)
C(13b)	0.3646(3)	0.3627(2)	0.12508(9)	0.0222(9)
C(13c)	0.5049(3)	0.2535(2)	0.14576(9)	0.0200(8)

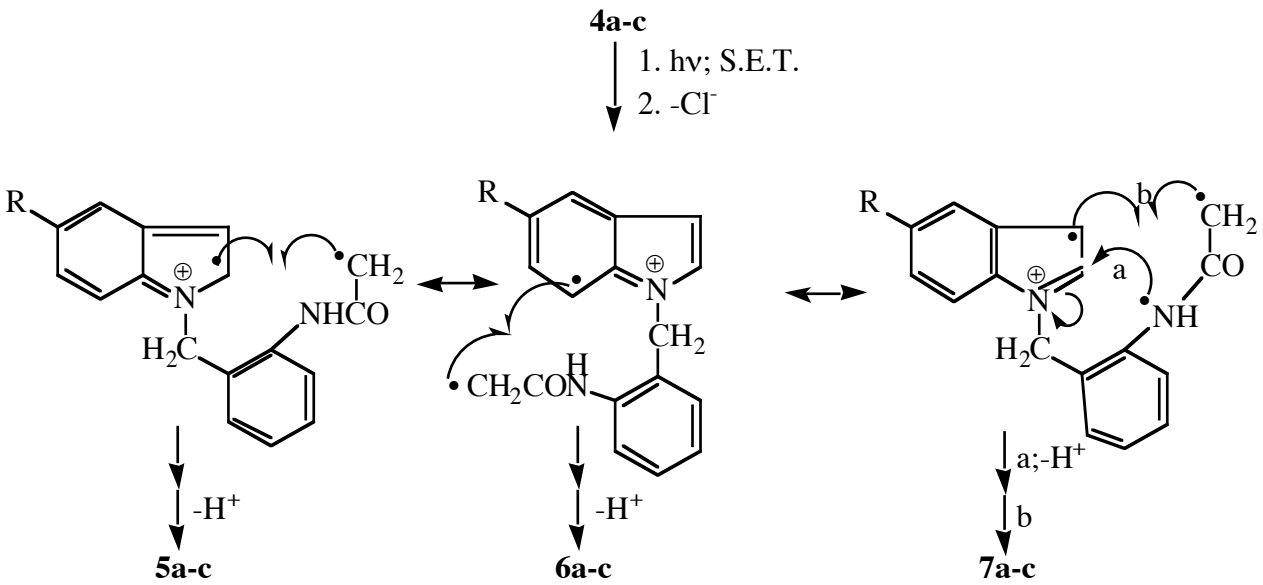


Figure 4. Pathways to cyclization products.

Photolysis of the readily available chloroacetamides (**4a-c**) provides an entry to a number of novel heterocyclic systems.

EXPERIMENTAL PROCEDURE

General Procedures:

All melting points were determined using a Reichert hot-stage melting point apparatus and are uncorrected. The ^{1}H and ^{13}C NMR were determined at 300.73 and 75.63 MHz respectively with a

Varian Unity-300 spectrometer. Unless otherwise stated, the spectra were obtained from solutions in $CDCl_3$ and referenced to TMS (proton) and chloroform mid-line (77) (carbon). Chemical shifts of the outer peaks are given for specified multiplet patterns in the ^{1}H-NMR spectra. MS (CI) were obtained using Shimadzu QP-5000 spectrometer and the direct insertion technique with an electron beam energy of 70 eV and a source temperature of 250^{o}C. In the CI MS, isobutane was used as the ionizing gas. High resolution (CI) MS (for MH^+) were run using a VG Autospec spectrometer operating at 70 eV and source temperature 250^{o}C with PFK reference and methane as the ionizing gas. IR spectra were recorded on a BOMEM MB-154 FTIR using KBr discs. TLC was performed on Merck silica gel 60 F_{254} on aluminum sheets or Merck aluminum oxide 60 F_{254} on aluminum sheets. R_f values were recorded from the center of spots. All chromatographic solvent proportions are volume for volume. Column chromatography was performed using Merck Kieselgel 60 silica gel or Merck aluminum oxide 60 F_{254} neutral (Type E) under medium pressure. Solvents were removed under reduced pressure by rotary evaporation, and organic solvent extracts were dried with anhydrous Na_2SO_4. Light petroleum had a boiling range of 60-80^{o}C. In addition to the standard abbreviations of this journal we use: DCM (dichloromethane), EtOAc (ethyl acetate), MeOH (methanol), and EtOH (ethanol).

Alkylation Procedure

1-[2-Nitrophenyl)methyl]-1H-indole (**2a**)

A stirred suspension of sodium hydride (1.3g of *ca* 50% dispersion in mineral oil; 0.65g ; 27.1 mmol) in dry DMF (25 mL) under a N_2 atmosphere was cooled to 0-5^{o}C and 1*H*-indole (**1a**) (2.9 g, 25 mmol) in DMF solution (75 mL) was added dropwise, with stirring over 30 min. Stirring was continued with cooling for a further 30 min and then to rt for 2 h. At this point excess DMF (275 mL) was added to ensure solution of the indole sodium salt at -60^{o}C and the resulting yellowish solution was cooled to -60^{o}C in a dry ice/ acetone bath. To the cold solution a solution of 2-nitrobenzyl bromide (6.85 g, 32 mmol) in DMF (25 mL) was added dropwise and the deep red mixture allowed to stir overnight with warming to rt. Approximately 95% of the DMF was removed under high vacuum from the resulting pale yellow slurry and the remainder was poured into a mixture of water and ice (400 mL). The slightly gummy solid was allowed to stir rapidly for 4 h, suction filtered, washed with cold water, and air dried to give **2a** (6.9g) as a dull yellow solid. Recrystallization from ethanol gave **2a** (total yield 4.85 g, 77%) as yellow crystals; mp 90.5-92^{o}C. ^{1}H-NMR ($CDCl_3$) δ: 5.75 (s, 2H, CH_2N), 6.47 (dd, J = 4.4 Hz, J = 9.3 Hz, 1H, H-6'), 6.63 (d, J = 3.2 Hz, 1H, H-3), 7.10-7.19 (m, 4H, H-2, H-6, H-5, and H-4'), 7.35-7.44 (m, 2H, H-7 and H-5'), 7.69 (d, J = 8.6 Hz, 1H, H-4), 8.16 (d, J = 9.5 Hz, 1H, H-3'). ^{13}C-NMR ($CDCl_3$) δ: 47.53 (CH_2), 102.68 (C-3), 109.42 (C-7); 120.00, 121.19, 122.18, 125.14, 128.16, 128.30, 128.42 (all ArC-H), 128.73 (C-3a); 133.52 (C-1'), 134.14 (C-3'), 136.27 (C-7a), 147.14 (C-NO_2). HRMS(CI) *m/z* (accurate MS 253.0979, $C_{15}H_{13}N_2O_2$ requires 253.0977).

The above procedure was followed for the preparations of **2b** and **2c** with the modifications noted below.

5-Methoxy-1-[2-nitrophenyl)methyl]-1H-indole (**2b**)

This compound was prepared from 5-methoxy-1*H*-indole (**1b**) (1.47g, 10 mmol). The resulting gummy material was taken up in DCM, the aqueous layer extracted with DCM (3 x 50 mL), the combined extracts dried, and evaporated under vacuum to give an orange oil. Trituration under diethyl ether yielded a tan crystalline product (total yield 1.7g) Recrystallization from ethanol gave **2b** (0.5g 20%) as yellow crystals; mp 117-119^{o}C. A repeat of this procedure on 0.04 mole scale resulted in a 81% yield of **2b**.

^{1}H-NMR ($CDCl_3$) δ: 3.85 (s, 3H, CH_3O), 5.75 (s, 2H, CH_2N), 6.45 (d, J = 9.0 Hz, 1H, H-6'), 6.55 (dd, J = 0.7 Hz, J = 3.2 Hz, 1H, H-3), 6.82 (dd, J = 2.4 Hz, J = 8.8 Hz, 1H, Ar), 7.02 (d, J = 8.8 Hz, 1H, Ar), 7.1-7.2 (m, 2H, H-2 and Ar), 7.36-7.42 (m, 2H, Ar), 8.16 (d, J = 9.5 Hz, 1H, H-3'). ^{13}C-NMR ($CDCl_3$) δ: 47.72 (CH_2), 55.82 (CH_3), 102.21 (ArC-H), 102.88 (C-3), 110.20 (ArC-H), 112.49 (C-7), 125.13 (C-2), 128.17 (ArC-H), 128.30 (ArC-H), 129.01 (ArC-H), 129.19 (C-3a), 131.54 (C-7a), 134.16 (ArC-H), 134.30 (C-1'), 147.11 (C-NO_2), 154.45 (C-OCH_3). HRMS(CI) *m/z* (accurate MS 283.1074, $C_{16}H_{15}N_2O_3$ requires 283.1083).

5-Fluoro-1-[2-nitrophenyl]methyl]-1H-indole **(2c)**

This compound was prepared from 5-fluoro-1*H*-indole (**1c**) (5.4 g, 40 mmol). The resulting orange oil was taken up in hot methanol, allowed to crystallize, and filtered, and the filtrate concentrated to yield a second crop of crystals. The total yield of yellow crystalline (**2c**) was 6.7 g (71%); mp 118-119°C (methanol). ^{1}H-NMR ($CDCl_3$) δ: 5.75 (s, 2H, CH_2N), 6.47 (dd, J = 4.2 or 5.6 Hz, J = 9.3 Hz, 1H, H-6'), 6.59 (d, J = 3.2 Hz, 1H, H-3), 6.91 (ddd, J = 2.4 Hz, J = 8.8 Hz, J = 9.3 Hz, 1H, Ar), 7.05 (dd, J = 4.2 Hz, J = 8.8 Hz, 1H, Ar), 7.18 (d, J = 3.2 Hz, 1H, H-2), 7.32 (dd, J = 2.4 Hz, J = 9.5 Hz, 1H, Ar), 7.38-7.48 (m, 2H, Ar), 8.17 (d, J = 9.5 Hz, 1H, H-3'). ^{13}C-NMR ($CDCl_3$) δ: 47.86 (CH_2), 102.56 (ArC-H), 102.62 (C-3), 105.98 (d, J = 23 Hz, C^{13}-F^{19}, C-6), 110.04 (ArC-H), 110.18 (ArC-H), 110.98 (d, J = 26 Hz, C^{13}-F^{19}, C-4), 110.80 ArC-H), 125.27 (C-2), 127.98 (ArC-H), 128.48 (ArC-H), 128.92 (C-3a), 130.08 (ArC-H), 132.81 (ArC-H), 133.90 (C-1'), 134.27 (C-7a), 147.02 (NO_2), 158.10 (d, J = 233 Hz, C^{13}-F^{19}, C-F). HRMS(CI) m/z (accurate MS 271.0875, $C_{15}H_{12}N_2O_2F$ requires 271.0883).

Reduction Procedure

1-[(2-Aminophenyl)methyl]-1H-indole **(3a)**

A solution of **2a** (4.15 g, 16.5 mmol), 10% Pd/C (1 g), and 2 drops of conc. HCl in THF (100 mL) was stirred under an H_2 atmosphere at rt overnight. The catalyst was removed by filtration, washed with DCM (5 x 10 mL), and the filtrate dried and evaporated to give an orange oil. The oil was taken up in minimal hot ethanol and the crystals obtained suction filtered to yield **3a** as a tan crystalline solid (1.3 g, 36 %) pure by TLC (silica gel; hexane/DCM, 1:1); mp 79-80.5°C (ethanol). ^{1}H-NMR ($CDCl_3$) δ: 3.45 (s, 2H, NH_2), 5.15 (s, 2H, CH_2), 6.51 (dd, J = 0.7 Hz, J = 3.2 Hz, 1H, H-3), 6.65 (d, J = 8.1 Hz, 1H, H-3'), 6.75 (ddd, J = 1.0 Hz, J = 7.3 Hz, J = 7.6 Hz, 1H, Ar), 6.90 (d, J = 9.3 Hz, 1H, Ar), 6.99 (d, J = 3.2 Hz, 1H, H-2), 7.09-7.24 (m, 3H, H-2, H-5 and H-6), 7.38 (d, J = 7.3 Hz, 1H, H-7), 7.65 (d, J = 7.3 Hz, 1H, H-4). ^{13}C-NMR ($CDCl_3$) δ: 47.45 (CH_2), 101.99 (C-3), 109.46 (C-7); 116.32, 118.91, 119.71, 121.08, 121.78, 127.25 (all ArC-H); 128.83 (C-3a), 129.20 (ArC-H), 129.75 (ArC-H), 136.33 (C-7a), 144.88 (C-NH_2). HRMS(CI) *m/z* (accurate MS 223.1225, $C_{15}H_{15}N_2$ requires 223.1235).

The above procedure was followed for the preparation of **3b** and **3c** with the modifications noted below.

1-[2-Aminophenyl]methyl]-5-methoxy-1H-indole **(3b)**

Starting from compound (**2b**) on a 4 mmol scale a crude orange oil was obtained which was taken up in hot ethanol (3 mL) and the crystals obtained suction filtered to yield a tan solid (0.5g). The filtrate was reduced under vacuum to yield further solid product (0.45g). The total yield of tan crystalline (**2b**) was 0.95 g (94%); mp 118-120°C (ethanol). ^{1}H-NMR ($CDCl_3$) δ: 3.45 (s, 2H, NH_2), 3.83 (s, 3H, CH_3O),

5.15 (s, 2H, CH_2), 6.40 (dd, J = 0.7 Hz, J = 3.2 Hz, 1H, H-3), 6.67 (d, J = 8.1 Hz, 1H, Ar), 6.76 (ddd, J = 1.0 Hz, J = 7.3 Hz, J = 7.3 Hz, 1H, Ar), 6.86 (dd, J = 2.4 Hz, J = 8.8 Hz, 1H, Ar), 7.94-7.0 (m with prominent d, J = 3.2 Hz, 2H, H-2 and Ar), 7.10 (d, J = 2.2 Hz, 1H, Ar), 7.15 (ddd, J = 1.22 Hz, J = 7.8 Hz, J = 9.0 Hz, 1H, Ar), 7.26 (d, J = 8.8 Hz, 1H, Ar). ^{13}C-NMR ($CDCl_3$) δ: 47.75 (CH_2), 55.86 (CH_3), 101.56 (ArC-H), 102.83 (C-3); 110.24, 112.06, 116.34, 118.92 (all ArC-H); 121.13 (C-1'), 127.86 (C-2), 129.20 (C-3a), 129.25 (ArC-H), 129.74 (ArC-H), 131.71 (C-7a), 144.92 (C-NH_2), 154.26 (C-OCH_3). HRMS(CI) *m/z* (accurate MS 253.1333, $C_{16}H_{17}N_2O$ requires 253.1341)

1-[2-Aminophenyl)methyl]-5-fluoro-1H-indole **(3c)**

Starting from compound (**2c**) on a 23 mmol scale the resulting orange oil was taken up in DCM, washed with dilute $NaHCO_3$, the solvent dried and evaporated. Column chromatography on silica gel (hexane/DCM, 1:1) eluted the product as a pale green oil (4.63 g) which slowly crystallized. A portion was recrystallized from methanol to give **3c** (3.36 g, 61%) as off-white crystals; mp 81-82.5°C. ^{1}H-NMR ($CDCl_3$) δ: 3.48 (s, 2H, NH_2), 5.15 (s, 2H, CH_2), 6.48 (d, J = 3.2 Hz, 1H, H-3), 6.70 (d, J = 8.1 Hz, 1H, Ar), 6.77 (ddd, J = 1.0 Hz, J = 7.3 Hz, J = 7.6 Hz, 1H, Ar), 6.86-7.0 (m, 2H, Ar), 7.06 (d, J = 3.2 Hz, 1H, H-2), 7.17 (ddd, J = 1.2 Hz, J = 7.6 Hz, J = 7.8 Hz, 1H, Ar), 7.23-7.31 (m, 2H, Ar). ^{13}C-NMR($CDCl_3$) δ: 47.79 (CH_2), 101.87 (ArC-H), 101.93 (C-3), 105.50 (ArC-H), 105.79 (d, J = 24 Hz, C^{13}-F^{19}, C-6), 109.98 (ArC-H), 110.19 (d, J = 21 Hz, C^{13}-F^{19}, C-4), 110.20 (ArC-H), 116.41 (ArC-H), 119.02 (ArC-H), 120.75 (C-3a), 128.90 (ArC-H), 129.34 (ArC-H), 129.66 (ArC-H), 132,92 (C-7a), 144.80 (C-NH_2), 157.95 (d, J = 234, C^{13}-F^{19},C-F). HRMS(CI) m/z (accurate MS 241.1134, $C_{15}H_{14}N_2F$ requires 241.1141).

Chloroacetylation Procedure

N-[(2-(1'-1H-Indolyl)methyl)phenyl]chloroacetamide **(4a)**

A stirred suspension of **3a** (0.33 g, 1.5 mmol) and sodium carbonate (0.6 g, 5.6 mmol) in dry DCM (15 mL) was cooled to 0-5°C and chloroacetyl chloride (0.43 g, 3.7 mmol) in DCM (8 mL) was added in 0.5 mL portions over 10 min. Stirring was continued with cooling for a further 30 min. and the reaction then allowed to warm to rt with stirring overnight. Distilled water (50 mL) was added to the reaction, the layers separated, and the aqeous layer extracted with DCM (3 x 10 mL). The extracts were combined, dried and solvent removed under vacuum to yield a pale yellow oil which yielded an off-white solid. Recrystallization from methanol gave **4a** (0.36 g, 82%) as colorless, fluffy crystals; mp 120-122°C. ^{1}H-NMR ($CDCl_3$) δ: 4.05 (s, 2H, CH_2Cl), 5.30 (s, 2H, benzylic), 6.55 (d, J = 2.7 Hz, 1H, H-3), 7.00 (d, J = 3.2 Hz, 1H, H-2), 7.05 (d, J = 7.3 Hz, 1H, Ar), 7.1-7.3 (m, 4H, Ar), 7.34 (ddd, J = 1.2 Hz, J = 7.3 Hz, J = 8.1 Hz, 1H, H-6), 7.64 (d, J = 9.0 Hz, 1H, Ar), 7.66 (d, J = 8.6, 1H, H-4), 8.00 (s, 1H, N-H). ^{13}C-NMR ($CDCl_3$) δ: 42.68 (CH_2 benzyl), 47.33 (CH_2Cl), 102.59 (C-3), 109.56 (C-7), 119.93 (Ar), 121.15 (C-1'), 121.96 (C-3'), 125.05 (C-2), 126.99 (C-3a); 127.4, 128.84, 128.93, 129.18, 130.42 (all ArC-H); 134.14 (C-7a), 136.40 (C-NH), 164.56 (CO). HRMS(CI) m/z (accurate MS 299.0948, $C_{17}H_{16}N_2OCl$ requires 299.0951). *Anal.* Calcd for $C_{17}H_{15}N_2O$ Cl: C, 68.44; H, 5.07; N, 9.40. Found: C, 68.44; H, 5.17; N, 9.45.

The above procedure was followed for the preparations of **4b** and **4c** with the modifications noted below.

***N*-{2-[1'-(5'-Methoxy-1H-indolyl)methyl]phenyl}chloroacetamide (4b)**

This product was prepared from compound (**3b**) (3.78 g, 15 mmol) to yield a pale orange oil which was chromatographed on silica gel (light petroleum/DCM, 3:7) to give **4b** as an off-white solid. Recrystallization from methanol gave **4b** (2.1 g, 43%) as colorless crystals; mp 132-133°C. ^{1}H-NMR ($CDCl_3$) δ: 3.83 (s, 3H, CH_3O), 4.03 (s, 2H, CH_2Cl), 5.23 (s, 2H, benzylic), 6.47 (d, J = 3.2 Hz, 1H, H-3), 6.84 (dd, J = 2.4 Hz, J = 9.0 Hz, 1H, Ar), 6.96 (d, J = 3.2 Hz, 1H, H-2), 7.04 (d, J =7.6 Hz, 1H, Ar), 7.10 (d, J = 2.4 Hz, 1H, Ar), 7.14 (d, J = 8.8 Hz, 1H, Ar), 7.20 (ddd, J = 1.2 Hz, J = 7.8 Hz, J = 8.8 Hz, 1H, Ar), 7.35 (ddd, J = 1.2 Hz, J = 7.8 Hz, J = 8.8 Hz, 1H, Ar), 7.63 (d, J = 7.6 Hz, 1H, H-3'), 8.01 (s, 1H, N-H). ^{13}C-NMR ($CDCl_3$) δ: 42.68 (CH_2), 47.57 (CH_2), 55.81 (CH_3), 102.13 (ArC-H), 102.82 (C-3), 110.33 (ArC-H), 112.22 (C-7), 124.96 (ArC-H), 126.93 (C-2); 128.02, 128.94, 129.15, 129.29 (all ArC-H); 130.36 (C-3a), 131.73 (C-7a), 134.18 (C-NH-), 154.35 (C-OCH_3), 164.56 (CO). HRMS(CI) *m/z* (accurate MS 329.1033, $C_{18}H_{18}N_2O_2{}^{35}Cl$ requires 329.1057). *Anal.* Calcd for $C_{18}H_{17}N_2O_2Cl$: C, 65.83; H, 5.22; N, 8.54. Found: C, 65.83; H, 5.13; N, 8.10.

***N*-{2-[1'-(5'-Fluoro-1H-indolyl)methyl]phenyl}chloroacetamide (4c)**

This product was prepared from compound (**3c**) (3.36g, 14 mmol) to yield a pale orange solid. Trituration under DCM gave **4c** as a white solid (3.2 g). The filtrate was concentrated and recrystallized from methanol to yield further **4c** (0.35 g) for a total yield of pure **4c** of 3.55 g (80%); mp 142-143°C. ^{1}H-NMR ($CDCl_3$) δ: 4.06 (s, 2H, CH_2Cl), 5.27 (s, 2H, benzylic), 6.95 (dd, J = 0.7 Hz, J = 3.2 Hz, 1H, H-3), 6.92 (ddd, J = 2.4 Hz, J = 9.0 Hz, J = 9.0 Hz, 1H, Ar), 7.01 (d, J = 7.8 Hz, 1H, Ar), 7.04 (d, J = 3.2 Hz, 1H, H-2), 7.12-7.25 (m, 2H, Ar), 7.28 (dd, J = 2.4 Hz, J = 9.5 Hz, 1H, Ar), 7.37 (ddd, J = 1.2 Hz, J = 7.6 Hz, J = 7.8 Hz, 1H, Ar), 7.60 (d, J = 8.1 Hz, 1H, Ar), 8.02 (s, 1H, N-H). ^{13}C-NMR ($CDCl_3$) δ: 42.67 (CH_2), 47.58 (CH_2), 102.38 (ArC-H), 102.44 (C-3), 105.86 (d, J = 24 Hz, C^{13}-F^{19}, C-6), 110.31 (ArC-H), 110.33 (d, J = 26 Hz, C^{13}-F^{19}, C-4), 125.18 (C-2), 127.16 (ArC-H), 129.03 (ArC-H), 129.10 (ArC-H), 130.38 (C-1'), 132.95 (C-3a), 133.95 (C-NH), 158.00 (d, J = 234 Hz, C^{13}-F^{19}, C5-F), 164.60 (CO). HRMS(CI) m/z (accurate MS 317.0834, $C_{17}H_{15}N_2OF^{35}Cl$ requires 317.0857).

General Information and Procedure for the Photolyses

The photolyses were conducted in a large quartz immersion well reactor (Model RQ 400) supplied by Photochemical Reactors Ltd., U.K. The lamp (16W) was housed internally and the solution was saturated with N_2 before and during photolysis.

A solution of **4a, b** or **c** in 50% acetonitrile/water v/v (360 mL) was purged with nitrogen for 30 min and then irradiated at rt with continued nitrogen purge for the indicated number of hours. The orange solution was made basic to pH 9-10 with 1 M NaOH and the acetonitrile removed under vacuum, The resulting yellowish slurry was suction filtered and the crude material obtained taken up in DCM (50 mL). Water (200 mL) was added to the filtrate and this was extracted with DCM (3 x 50 mL). The DCM extracts were combined with the crude product DCM solution, dried over anhydrous sodium sulfate, and solvent removed under vacuum to give the photolysates as orange foams or gums.

Photolysis of *N*-[(2-(1'-1H-Indolyl)methyl)phenyl]chloroacetamide (4a)

The solution of **4a** (0.299, 1.0 mmol) was photolysed for 8 h. TLC (silica gel, MeOH/DCM, 5:95) indicated a multi-component mixture with three major spots (R_fs: 0.84, 0.43 and 0.38). This procedure

was repeated twice more (on 1.5 mmol and 2 mmol scales) to yield a total of 1.5 g of orange gum. The gum was chromatographed on silica with DCM to give five fractions: 1 (24 mg, R_f 0.93 - starting material **4a**); 2 (200 mg, R_f 0.84); 3 (100 mg, R_f 0.43); 4 (325 mg - mixture of R_f 0.43 and 0.38); and 5 (175 mg, R_f 0.38). Fractions 2, 3 and 5 represent the following isolated yields: **7a** (200 mg, 18%), **5a** (100 mg, 9%), and **6a** (175 mg, 16%), all of which have a molecular MS of 262. These yields are based upon actual **4a** photolysed (5 mmol - fraction 1, 0.8 mmol). ^{1}H- NMR analysis of (fraction 4) indicated this two component mixture contained further **5a** (75 mg, 7%) and **6a** (250 mg, 23%) giving total percentage yields of these products of 16% and 39% respectively.

Fraction 2 was identified as *13b,13c-dihydro-8H-pyrrolo[2,3-b]indolo[5,5a,6-b,a]quinazolin-2(1H)-one* (**7a**) which was recrystallized from methanol to give colorless crystals; mp 195-197^{o}C. ^{1}H-NMR ($CDCl_3$) δ: 2.80 (d, J = 17.1 Hz, 1H, H-1), 3.18 (dd, J = 17.1 Hz, J = 7.8 Hz, 1H, H-1), 3.90 (m, 1H, H-13b), 4.63 (d, J = 17.7 Hz, 1H, H-8), 4.75 (d, J = 17.7 Hz, 1H, H-8), 5.44 (d, J = 6.4 Hz, 1H, H-13c), 6.59 (d, J = 8.1 Hz, 1H, H-10), 6.79 (ddd, J = 0.7 Hz, J = 6.6 Hz, J = 7.3 Hz, 1H, H-12), 7.06-7.20 (m, 4H, H-6, H-7, H-11, H-13), 7.22 (ddd, J = 1.7 Hz, J = 8.3 Hz, J = 8.8 Hz, 1H, H-5), 8.20 (d, J = 8.3 Hz, 1H, H-4). ^{13}C-NMR ($CDCl_3$) δ: 38.06 (CH_2, C-1), 38.22 (CH_2, C-13b), 45.08 (CH_2N, C-8), 76.34 (C-13c), 108.46 (ArC-H), 119.48 (ArC-H), 120.19 (ArC-H), 123.94 (ArC); 124.10, 124.60, 125.77, 126.98, 128.74 (all ArC-H); 129.58 (C-7a), 134.58 (ArC-H), 149.61 (ArC-H), 170.79 (CO). HRMS(CI) *m/z* (accurate MS 263.1184, $C_{17}H_{15}N_2O$ requires 263.1184). *Anal.* Calcd for $C_{17}H_{14}N_2O$: C, 77.83; H, 5.38; N, 10.68. Found: C, 78.22; H, 5.30; N, 10.10.

Fraction 3 was identified as *5,14-dihydroindolo[2,1-d][1,5]benzodiazocin-6(7H)-one* (**5a**) which was recrystallized from methanol to give off-white crystals; mp 268-270^{o}C. IR (KBr) ν_{max}: 3247 (NH), 1662 (C=O) cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 3.57 (s, 2H, C$\underline{H}_2$CO), 5.14 (s, 2H, benzylic), 6.39 (s, 1H, H-8), 7.11 (m, 1H, Ar), 7.27 (ddd, J = 1.2 Hz, J = 4.9 Hz, J = 7.1 Hz, 1H, Ar), 7.29 (dd, J = 1.2 Hz, J = 4.2 Hz, 1H, Ar), 7.34 (dd, J = 1.5 Hz, J = 7.6 Hz, 1H, Ar), 7.37-7.40 (m, 1H, Ar), 7.44 (dd, J = 1.7 Hz, J = 7.6 Hz, 1H, Ar), 7.47-7.58 (m, 2H, Ar), 8.50 (s, 1H, N-H). ^{13}C-NMR ($CDCl_3$) δ: 35.00 (CH_2, C-14), 45.28 (CH_2, C-7), 103.45 (C-8); 108.70, 119.79, 120.41, 121.56, 125.49 (all ArC-H); 127.85 (C-7a), 128.59 (ArC-H), 130.10 (ArC-H), 131.45 (ArC), 131.83 (ArC), 132.23 (ArC-H), 137.75 (ArC), 138.21 (C-11a), 171.06 (CO). HRMS(CI) *m/z* (accurate MS 263.1176, $C_{17}H_{15}N_2O$ requires 263.1184). *Anal.* Calcd for $C_{17}H_{14}N_2O$: C, 77.83; H, 5.38; N, 10.68. Found: C, 77.32; H, 5.36; N, 9.96.

Fraction 5 was identified as *8,13-dihydroindolo[7,7a,1,-d,e][1,6]benzodiazonin-7(6H)-one* (**6a**) which was recrystallized from methanol to give off-white crystals; mp 266-268^{o}C. IR (KBr) ν_{max}: 3185 (NH), 1663 (C=O) cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 3.53 (s, 2H, CH_2CO), 5.11 (s, 2H, benzylic), 6.50 (d, J = 3.2 Hz, 1H, H-2), 6.98 (m with prominent d, J = 7.1 Hz, 2H, Ar), 7.19 (d, J = 3.2 Hz, 1H, H-1), 7.27-7.42 (m, 3H, Ar), 7.50 (dd, J = 1.9 Hz, J = 7.1 Hz, 1H, Ar), 7.67 (m, 1H, Ar), 8.50 (s, 1H, N-H). ^{13}C-NMR ($CDCl_3$) δ: 39.23 (CH_2, C-13), 49.07 (CH_2, C-6), 102.75 (C-2), 119.01 (ArC); 120.27, 120.41, 127.18, 127.44, 128.45, 129.54 (all ArC-H); 131.17 (C-2a), 131.37 (ArC-H), 132.73 (ArC-H), 137.19 (ArC), 138.25 (ArC), 138.35 (C-14a), 176.68 (CO). HRMS(CI) *m/z* (accurate MS 263.1193, $C_{17}H_{15}N_2O$ requires 263.1184). *Anal.* Calcd for $C_{17}H_{14}N_2O$: C, 77.83; H, 5.38; N, 10.68. Found: C, 78.06; H, 5.42; N, 10.37.

Photolysis of *N-{2-[1'-(5'-Methoxy-1H-indolyl)methyl]phenyl}chloroacetamide* (4b)

The solution of **4b** (0.299, 1.0 mmol) was photolysed for 4 h. TLC (silica gel; EtOAc/DCM,1:9) indicated a four component mixture with three major components (R_fs: 0.64, 0.32 and 0.24). The

photolysis was repeated once more and then twice at a 1.5 mmol scale to yield a total of 1.57 g of photosylate as an orange gum. The gum was chromatographed on silica (EtOAc/DCM,1:9) to give 5 main fractions: 1 (73 mg, R_f 0.8 - starting material); 2 (302 mg, R_f 0.64); 3 (187 mg, R_f 0.32); 4 (41 mg - mixture of R_f 0.32 and 0.24); and 5 (556 mg, R_f 0.24). Fractions 2, 3 and 5 represent the following isolated yields: **7b** (302 mg, 22%), **5b** (187 mg, 14%) and **6b** (556 mg 40%) respectively, all of which have a molecular MS of 292. These yields are based upon actual **4b** photolysed (5 mmol - fraction 1, 0.25 mmol). ^{1}H-NMR analysis of fraction 4 indicated this two component mixture contained further **5b** (6 mg, 0.4%) and **6b** (35 mg, 3%) giving total percentage yields of these products of 14% and 43% respectively.

Fraction 2 was identified as *13b,13c-dihydro-12-methoxy-8H-pyrrolo[2,3-b]indolo[5,5a,6-b,a]quinazolin-2(1H)-one* (**7b**). Recrystallization from methanol gave colorless crystals; mp 209-211^{o}C. IR (KBr) ν_{max}: 1689 (C=O) cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 2.80 (d, J = 16.8 Hz, 1H, H-1), 3.16 (dd, J = 16.8 Hz, J = 7.8 Hz, 1H, H-1), 3.73 (s, 3H, CH_3O), 3.89 (m, 1H, H-13b), 4.55 (d, J = 17.8 Hz, 1H, benzylic), 4.74 (d, J = 17.83 Hz, 1H, benzylic), 5.43 (d, J = 6.1 Hz, 1H, H-13c), 6.50 (d, J = 8.6 Hz, 1H, H-10), 6.71 (dd, J = 2.0 Hz, J = 8.6 Hz, 1H, H-11), 6.78 (m, 1H, H-13), 7.06-7.20 (m, 2H, H-6, H-7), 7.23 (m with prominent d, J = 9.5 Hz, 1H, H-5), 8.22 (d, J = 9.5, 1H, H-4). ^{13}C-NMR ($CDCl_3$) δ: 38.10 (C-1), 38.82 (C-13b), 45.66 (CH_2,N, C-8), 56.01 (CH_3O), 77.71 (C-13c); 109.17, 112.01, 113.73, 120.33, 124.29, 125.05, 126.05, 127.19 (all ArC-H); 131.15, 134.88, 143.85, 154.11 (all ArC), 170.89 (CO). HRMS(CI) *m/z* (accurate MS 293.1284, $C_{18}H_{17}N_2O_2$ requires 293.1290). *Anal.* Calcd for $C_{18}H_{16}N_2O_2$: C, 73.94; H, 5.52; N, 9.59. Found: C, 74.28; H, 5.51; N, 9.21.

Fraction 3 has been identified as *5,14-dihydro-10-methoxyindolo[2,1-d][1,5]benzodiazocin-6(7H)-one* (**5b**). Recrystallization from methanol gave off-white crystals; mp 238-239.5^{o}C. IR (KBr) ν_{max}: 3153 (NH), 1669 (C=O) cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 3.54 (s, 2H, CH_2CO),3.89 (s, 3H, CH_3O), 5.09 (s, 2H, benzylic), 6.31 (s, 1H, H-8), 6.91 (dd, J = 2.4 Hz, J = 9.0 Hz, 1H, H-11), 7.02 (d, J = 2.4 Hz, 1H, H-9), 7.28 (dd, J = 1.2 Hz, J = 7.6 Hz, 1H, Ar), 7.34-7.40 (m, 2H, Ar), 7.45 (dd, J = 1.7 Hz, J = 7.6 Hz, 1H, Ar), 7.54 (dd, J = 1.7 Hz, J = 7.3 Hz, 1H, Ar), 8.52 (s, 1H, N-H). ^{13}C-NMR ($CDCl_3$) δ: 35.01 (CH_2, C-14), 45.51 (CH_2, C-7), 55.88 (CH_3O), 102.19 (C-8); 103.11, 109.44, 119.60, 125.48 (all ArC-H); 128.19 (C-8a), 128.61, 130.08, 131.46 (ArC), 132.23 (ArC-H), 132.33 (ArC-H), 133.10 (ArC), 138.13 (ArC), 154.14 (ArC), 170.90 (CO). HRMS(CI) *m/z* (accurate MS 293.1283, $C_{18}H_{17}N_2O_2$ requires 293.1290). *Anal.* Calcd for $C_{18}H_{16}N_2O_2$: C, 73.94; H, 5.52; N, 9.59. Found: C, 74.08; H, 5.43; N, 9.11.

Fraction 5 has been identified as *8,13-dihydro-4-methoxyindolo[7,7a,1-d,e][1,6]benzodiazonin-7(6H)-one* (**6b**). Recrystallization from methanol gave crystals with a pink tinge; mp 233-235^{o}C. IR (KBr) ν_{max}: 3178 (NH), 1667 (C=O) cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 3.47 (s, 2H, CH_2CO), 3.80 (s, 3H, CH_3O), 5.07 (s, 2H, benzylic), 6.41 (d, J = 3.2 Hz, 1H, H-2), 6.72 (d, J = 2.2 Hz, 1H, H-5), 6.95 (d, J = 2.2 Hz, 1H, H-3), 7.15 (d, J = 2.9 Hz, 1H, H-1), 7.27-7.42 (m, 3H, Ar), 7.65 (dd, J = 6.3 Hz, J = 9.0 Hz, 1H, Ar), 8.45 (s, 1H, N-H). ^{13}C-NMR ($CDCl_3$) δ: 39.10 (CH_2, C-13), 49.11 (CH_2, C-6), 55.74 (CH_3O), 101.88 (C-2), 116.98 (ArC-H), 119.88 (ArC); 127.44, 128.52, 129.55, 131.46 (all ArC-H); 131.81 (ArC), 133.40 (ArC-H); 133.50, 137.10, 138.27, 154.10 (all ArC), 176.23 (CO). HRMS(CI) *m/z* (accurate MS 293.1298, $C_{18}H_{17}N_2O_2$ requires 293.1290). *Anal.* Calcd for $C_{18}H_{16}N_2O_2$: C, 73.94; H, 5.52; N, 9.59. Found: C, 74.54; H, 5.55; N, 9.36.

Photolysis of *N-{2-[1'-(5'-Fluoro-1H-indolyl)methyl]phenyl}chloroacetamide* (4c)

The solution of **4c** (0.95, 3.0 mmol) was photolysed for 16 h. TLC (silica gel: DCM) indicated a three component mixture (R_fs: 0.7, 0.52 and 0.15). This photolysis was repeated twice more at the same scale to yield a total of 2.49 g of photolysate as an orange gum. The gum was triturated with ether to give a tan solid (1.45 g) whose TLC indicated two possible components. The ether was evaporated to give a foam (1.08 g) consisting of starting material and the R_f 0.52 component. Column chromatography of this foam on silica (DCM) gave 2 major fractions: 1 (228 mg, R_f 0.72 - starting material), and 2 (241 mg, R_f 0.52, **7c**). The above tan solid was chromatographed on silica (EtOAc/DCM, 1:9) to give two major fractions: 2'(97 mg, R_f 0.52, **7c**) and 3'(720 mg, R_f 0.15). Fraction 3'was found to be two components (R_fs 0.63 and 0.56) upon TLC with double development (neutral alumina: benzene/DCM, 1:9). The combined yield of **7c** was 338 mg, 18%). Fration 3' represents yields of **5c** and **6c** in the mixture of 14% and 28% respectively. These yields were based upon actual **4c** photolysed (5 mmol - fraction 1, 0.7 mmol) and ^{1}H-NMR analysis of three pertinent signals (fraction 3').

Fraction 2 was identified as *12-fluoro-13b,13c-dihydro-8H-pyrrolo[2,3-b]indolo[5,5a,6-b,a]quinazolin-2(1H)-one (***7c***)*. Recrystallization from methanol gave colorless crystals; mp 215-217^{o}C. IR (KBr) ν_{max}: 1689 (C=O) cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 2.78 (d, J = 16.9 Hz, 1H, H-1), 3.19 (dd, J = 16.9 Hz, J = 7.8 Hz, 1H, H-1), 3.91 (m, 1H, H-13b), 4.56 (d, J = 17.8 Hz, 1H, H-8), 4.76 (d, J = 17.8 Hz, 1H, H-8), 5.43 (d, J = 6.1 Hz, 1H, H-13c), 6.50 (dd, J = 3.9 Hz (H-F), J = 8.6 Hz, 1H, H-11), 6.82-6.94 (m, 2H, H-10, H-13), 7.08-7.28 (m, 3H, H-5, H-6, H-7), 8.22 (d, J = 8.1 Hz, 1H, H-4). ^{13}C-NMR ($CDCl_3$) δ: 38.04 (C-1), 38.56 (C-13b), 45.62 (C-8), 77.63 (C-13c), 109.00 (ArC-H), 109.09 (ArC-H), 112.52 (d, J = 25 Hz, C^{13}-F^{19}, C11-F), 115.13 (d, J = 23 Hz, C^{13}-F^{19}, C13-F), 120.41 (ArC-H), 123.96 (ArC), 124.46 (ArC-H), 126.05 (ArC-H), 127.31 (ArC-H), 131.29 (ArC), 131.39 (ArC), 134.72 (ArC), 146.00 (ArC)), 157.37 (d, J = 237Hz, C^{13}-F^{19}, C12-F), 170.05 (CO). HRMS(CI) *m/z* (accurate MS 281.1093, $C_{17}H_{14}N_2OF$ requires 281.1090). *Anal.* Calcd for $C_{17}H_{13}N_2OF$: C, 72.85; H, 4.67; N, 9.99. Found: C, 73.36; H, 4.83; N, 10.13.

A portion (100 mg) of the fraction 3 mixture was rechromatographed on alumina (DCM) to give small amounts of two compounds. The first was identified as *10-fluoro-5,14-dihydroindolo[2,1-d][1,5]benzodiazocin-6(7H)-one* (**5c**) (15mg). Recrystallization from methanol gave **5c** (4 mg) colorless crystals; mp 276-278^{o}C. IR (KBr) ν_{max}: 3191 (NH), 1689 (C=O) cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 3.56 (s, 2H, CH_2CO), 5.14 (s, 2H, benzylic), 6.36 (s, 1H, H-8), 7.00 (ddd, J = 2.5 Hz, J = 9.1 Hz, J = 9.1 Hz(H-F), 1H, H-11), 7.20 (dd, J = 2.5 Hz, J = 9.4 Hz(H-F), 1H, H-9), 7.30 (d, J = 7.8 Hz, 1H, H-1), 7.36-7.42 (m, 2H, ArH), 7.46 (ddd, J = 1.3 Hz, J = 7.6 Hz, J = 7.6 Hz, 1H, H-2), 7.55 (dd, J = 1.3 Hz, J = 7.5 Hz, 1H, H-4), 8.10 (s, 1H, N-H). ^{13}C-NMR ($CDCl_3$) δ: 35.00 (CH_2), 45.60 (CH_2), 103.41 (ArC-H), 103.46 (ArC-H), 105.25 (d, J = 24 Hz, C^{13}-F^{19}, C9-F), 109.23 (ArC-H), 109.32 (ArC-H), 109.80 (d, J = 26 Hz, C^{13}-F^{19}, C11-F), 125.55 (ArC-H), 128.13 (ArC), 128.78 (ArC-H), 130.29 (ArC-H), 131.29 (ArC), 132.27 (ArC-H), 133.46 (ArC), 134.39 (ArC), 138.04 (ArC), 157.87 (d, J = 234 Hz, C^{13}-F^{19}, C10-F), 170.31 (CO). HRMS(CI) *m/z* (accurate MS 281.1092, $C_{17}H_{14}N_2OF$ requires 281.1090).

The second compound was identified as *4-fluoro-8,13-dihydroindolo[7,7a,1-d,e][1,6]benzodiazonin-7(6H)-one* (**6c**) (30 mg). Recrystallization from methanol gave **6c** (15 mg) as colorless crystals; mp 258-262^{o}C. IR (KBr) ν_{max}: 3189 (NH), 1663 (C=O) cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ: 3.50 (s, 2H, CH_2CO), 5.11 (s, 2H, benzylic), 6.46 (d, J = 3.2 Hz, 1H, H-2), 6.84 (dd, J = 2.4 Hz, J = 9.7 Hz(H-F), 1H, H-5), 7.14 (dd, J = 2.4 Hz, J = 8.8 Hz(H-F), 1H, H-3), 7.23 (d, J = 3.2 Hz, 1H, H-1), 7.31-7.34 (m with prominent d, J = 9.3 Hz, 1H, H-10), 7.38-7.44 (m, 2H, H-11, H-12), 7.54 (m with prominent d, J = 9.3

Hz, 1H, H-9), 7.97 (s, 1H, N-H). ^{13}C-NMR ($CDCl_3$) δ: 38.82 (CH_2), 49.15 (CH_2), 102.37 (ArC-H), 102.42 (ArC-H), 104.77 (d, J = 22 Hz, C^{13}-F^{19}, C5-F), 115.13 (d, J = 26 Hz, C^{13}-F^{19}, C3-F), 120.07 (d, J = 9 Hz, C^{13}-F^{19}, C5a-F); 127.46, 128.71, 129.76, 131.48, 134.38 (all ArC-H); 134.96 (ArC), 136.92 (ArC), 138.04 (ArC), 157.47 (d, J = 237 Hz, C^{13}-F^{19}, C4-F), 175.63 (CO). HRMS(CI) *m/z* (accurate MS 281.1099, $C_{17}H_{14}N_2OF$ requires 281.1090).

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16. **Structure Determinations:** Full spheres ($2\theta_{max}$ = 58°) of area-detector diffractometer data were measured at *ca*. 153 K (Bruker AXS instrument; monochromatic Mo *K*α radiation, λ = 0.7107_3 Å; ω scans) yielding $N_{t(otal)}$ reflections, reducing to *N* unique, *via* the proprietary software, N_o with $F > 4\sigma(F)$ being considered 'observed' and used in the full matrix least squares refinement, refining anisotropic thermal parameter forms for O,N,C and $(x, y, z, U_{iso})_H$ for **5b**, **7a**, the latter parameters constrained at estimates for **6a**. Conventional residuals *R*, R_w (statistical weights) on |*F*| are recorded at convergence. Neutral atom complex scattering factors were used within the Xtal 3.5 program system (S. R. Hall, G. S. D. King, and J. M. Stewart, University of Western Australia, Lamb, Perth, 1997). Full crystallographic data tables for **5b**, **6a**, and **7a** are available from the Cambridge Crystallographic Data Centre.
Crystal/refinement data – **5b** – $C_{18}H_{16}N_2O_2$, *M* = 292.3. Monoclinic, space group $P2_1/c$ (C_{2h}^5, No.14), *a* = 7.3956(8), *b* = 19.819(2), *c* = 10.423(1) Å, β = 107.402(3)°, *V* = 1457.$_8$ Å^3. D_c (*Z* = 4) = 1.33_2 g cm^{-3}; *F*(000) = 616. μ_{Mo} = 0.88 cm^{-1}; specimen: 0.40 x 0.20 x 0.06 mm (plate; no correction). N_t = 16863, *N* = 3671 (R_{int} = 0.023), N_o = 2959; *R* = 0.038, R_w = 0.048; n_υ=263, $|\Delta\rho_{max}|$

= 0.30(2) e Å^{-3}.

6a – $C_{17}H_{14}N_2O$, M = 262.3. Triclinic, space group $P\bar{1}$ (C_i^1, No.2), a = 14.404(3), b = 14.594(3), c = 15.350(3) Å, α = 69.588(3), β = 70.769(3), γ = 65.314(3)°, V = 2683 Å^3. D_c (Z = 8) = 1.29$_9$ g cm^{-3}; F(000) = 1104. μ_{Mo} = 0.82 cm^{-1}; specimen: 0.45 x 0.22 x 0.15 mm (no correction). N_t = 30460, N = 13141 (R_{int} = 0.046), N_o = 7944; R = 0.083, R_w = 0.11; n_υ=723, $|\Delta\rho_{max}|$ = 0.48(3) e Å^{-3}.

7a – $C_{17}H_{14}N_2O$, M = 262.3. Orthorhombic, space group $P2_12_12_1$ (D_2^4, No.19), a = 6.735(1), b = 10.529(2), c = 17.909(4) Å, V = 1270 Å^3. D_c (Z = 4) = 1.37$_2$ g cm^{-3}; F(000) = 552. μ_{Mo} = 0.85 cm^{-1}; specimen: 0.40 x 0.12 x 0.12 mm; 'T'$_{min,\ max}$ ('SADABS' 'empirical' absorption correction) = 0.84, 0.98. N_t = 14539, N = 1902 (R_{int} 0.030; 'Friedel pairs' merged after indecisive refinement of absolute structure), N_o = 1672; R = 0.034, R_w = 0.039; n_υ=238, $|\Delta\rho_{max}|$ = 0.21 e Å^{-3}.

17. Molecular modelling was performed on a Silicon Graphics 02 workstation using Spartan (v.5.0) software by Wavefunction, Inc., Irvine, CA. The geometry of the compound was optimised *in vacuo* (as an isolated molecule) using the Merck Force Field (MM FF94; T.A. Halgren, *J. Computational Chem.*, 1996, **17**, 490 and following papers in the same issue) as implemented in Spartan.