Organic & Biomolecular Chemistry

Cite this: *Org. Biomol. Chem.*, 2012, **10**, 2026

www.rsc.org/obc

PAPER

Switching between ring closed and open N-incorporated heterocycles with tuneable charges and modular reactivity based upon 5-(2-bromoethyl) phenanthridinium bromide†

Roslyn Eadie, Craig Richmond, Samantha Moreton and Leroy Cronin*

Received 9th October 2011, Accepted 20th December 2011
DOI: 10.1039/c2ob06708k

5-(2-bromoethyl)phenanthridinium bromide (BEP) undergoes a 3-step-one-pot cyclisation reaction with primary amines allowing the facile synthesis of a vast library of heterocycles. A diverse range of primary aryl amines were explored as reactants to gain insight into the product isolated as a result of the steric and electronic effects of the aryl precursors. Analysis and reaction monitoring with UV-vis and NMR spectroscopy revealed that excessively electron withdrawing groups and sterically hindered amines do not allow for isolation of the common neutral tetrahydroimidazophenanthridine (TIP) structure but allow either the isolation of the charged dihydroimadazophenanthridinium (DIP) or aminoethylphenanthridinium (AEP) products.

Introduction

Heterocyclic organic molecules are vital components of all biological systems, for example, DNA base units, amino acids and vitamins, as well as naturally occurring drugs such as morphine and quinine.[1] Their susceptibility to structural modifications allows the discovery of new systems which could lead to further applications in the pharmaceutical industry[2–4] as herbicides, pesticides,[5] and drugs, making them excellent candidates for further study. As such many studies have focused on nitrogen containing heterocycles as they generally have a high affinity for DNA,[4,6,7] and therefore form a strong platform from which to create new anticancer therapeutics, and a tool box to explore small-molecule nucleic acid interactions.

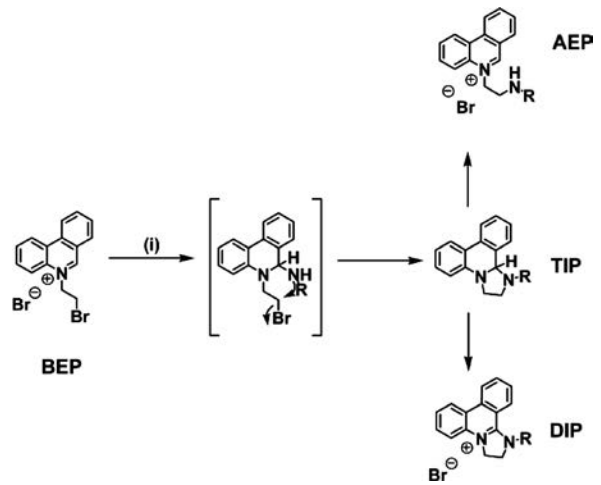
A short time ago a new family of nitrogen containing heterocycles based on a phenanthridinium framework was discovered by Cronin and Parenty. This 3-step-one-pot cyclisation reaction was found to be general between the phenanthridinium framework and a large range of primary amines yielding charged planar aromatic dihydroimidazophenanthridinium cations (DIPs).[8] Due to the features of the DIP structures, it was originally thought that they would be suitable DNA targeting agents; their cationic nature allows for attraction to anionic substances such as the phosphate backbone and the flat aromatic framework also makes intercalation between bases pairs a potential interaction.[9] In addition, the dihydroimidazolium ring helps prevent reduction[8] and provides resistance to pseudo base formation, a common drawback of phenanthridinium-based anticancer agents.[10] Avoiding these structural changes is important for retention of activity as they disrupt the planarity and remove the positive charge, the features necessary for their biological function.[11] Based on these rationales, studies were conducted on a range of DIP derivatives, where it was found that they showed promise as candidates for application in cancer therapy because of their DNA binding abilities and potent and unusual activity in a range of cancer cell lines.[8,12,13] However, a major drawback with the cationic DIP framework was their low therapeutic indices and toxic side-effects thought to be caused by non-specific DNA binding or by other mechanisms such as membrane insertion.[12,14]

The 3-step-one-pot cyclisation reaction, reported by Cronin and Parenty, involves nucleophilic attack by a primary amine at the α-position of 5-(2-bromoethyl)phenanthridinium bromide (BEP) followed by a 5-*exo-tet* cyclisation and a final oxidation step to give the DIP product. The cyclised intermediate formed prior to oxidation is the tetrahydroimidazophenanthridine (TIP) structure, for which a method of isolation has only recently been reported.[15] Isolation of the TIPs not only provided mechanistic information on this new reaction sequence but also allowed for the formation of another new family of compounds, the aminoethylphenanthridiniums (AEPs)[16] (Scheme 1). These AEPs form *via* protonation and ring opening of the cyclic TIP intermediates.

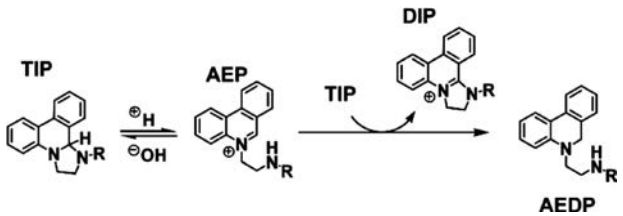
Contrary to the DIP, the TIP structure is neutral and non-planar and could therefore reduce the toxic side-effects

WestCHEM, School of Chemistry, University of Glasgow, Glasgow, United Kingdom, G12 8QQ. E-mail: Lee.Cronin@glasgow.ac.uk; Tel: + 44 141 330 6650

†Electronic supplementary information (ESI) available: ^{1}H NMR spectra of isolated compounds and UV-vis spectra for kinetic experiments. See DOI: 10.1039/c2ob06708k



Scheme 1 Synthetic outline for the preparation of the TIP, DIP and AEP heterocycles (i) NH_2R (1 eq.) and triethylamine (3 eq.) in chloroform.

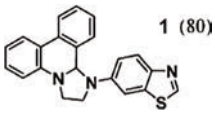
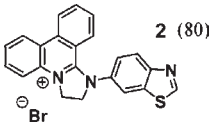
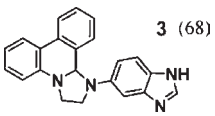
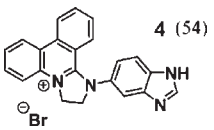
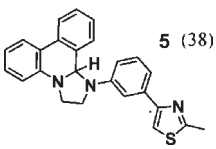
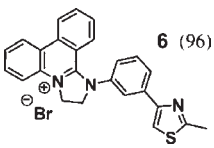


Scheme 2 Relationship between the TIP, DIP AEP and AEDP structures by way of pH control.

previously observed for the DIPs.[17] Similar neutral non-planar heterocycles have also been shown to have applications in antibacterials, fungicides and other biological actions.[18–20] Despite this, the TIP structures have been much less studied due to their reduced stability in comparison to the DIP structures. This lower stability comes from their susceptibility towards oxidative and acidic conditions, making isolation more difficult. For these reasons successful TIP isolation has been to a greater extent more challenging and until now attempts to expand the library of TIP compounds have not yet had the same level of success as was experienced with the DIPs. During the expansion of the TIP library it was observed that isolation relied upon the substituent of the amine chosen for the reaction being sufficiently electron withdrawing. This was because in order to reduce the possibility of 'hydride loss' (oxidation) the availability of the nitrogen lone pair had to be moderated. Equally it could not be excessively electron withdrawing as this consequently caused the nucleophilic nitrogen to be too weak to attack the α-position of the BEP; finding the exact balance point was therefore crucial for controlling the outcome of these reactions.[15]

The reversible relationship between the TIP and AEP structures is another aspect that was discovered and the equilibrium between these two structures can be related to the pK_a of the primary amine reactants. Aliphatic amines tend to have a higher pK_a than aryl amines, thus increasing the degree of protonation at lower pH and hence production of the corresponding AEP *via* ring opening (Scheme 2). A relationship between pK_a and TIP oxidation was also established. Both of these features are important because the AEP can act as a hydride acceptor, irreversibly consuming the TIP to generate the DIP and 5-(2-aminoethyl)-5,6-dihydrophenanthridine (AEDP). The inherent co-existence of the TIP reductant and AEP oxidant is the reason only TIP derivatives produced mainly from substituted aryl amines have been successfully isolated.[15]

Table 1 Selected aryl amines and their product percentage yields using the standard conditions for synthesis

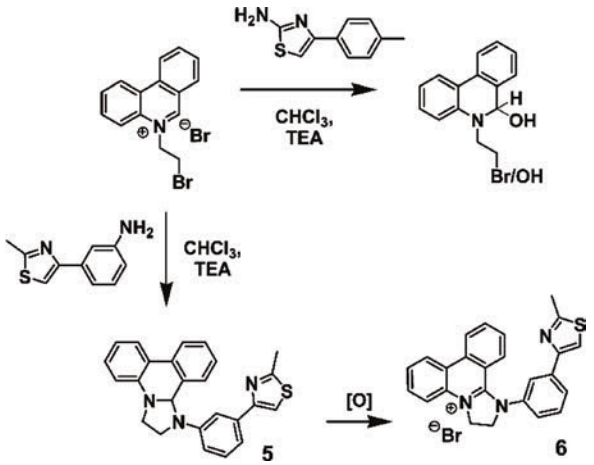
Amine	TIP(% yield)	DIP(% yield)
6-benzo-thiazolamine	 **1** (80)	 **2** (80)
2-benzo-thiazolamine	– (0)	– (0)
6-amino-benzimidazole	 **3** (68)	 **4** (54)
2-amino-benzimidazole	– (0)	– (0)
2-methyl-4-(3-aminophenyl) thiazole	 **5** (38)	 **6** (96)
2-amino-4-(*p*-tolyl) thiazole	– (0)	– (0)

Herein we report the study of the reaction pathways observed as a result of the amine substituent when reacted with the BEP starting material. Three topics were studied to gain further insight into this influence: Electronic effects from aryl substituents, steric effects from *ortho* substituents, and effects of neighbouring hydroxyls and ring-based nitrogen atoms, the latter being a finer extension of the former two.

Results and discussion

Electronic effects

The first group of amines considered comprised a set of amine reactants where the amine itself was directly conjugated to two other highly electronegative elements (nitrogen and sulphur) and their isomers in which the amine is at the other end of the molecule and not directly conjugated to them (Table 1 and Scheme 3). When the nucleophilic nitrogen was conjugated to the benzene ring, and not directly to the other electronegative elements in the amine structure, it was possible to isolate the corresponding TIP structures using the normal TIP reaction method (Scheme 3). This method involves adding the amine (1 eq.) along with base, triethylamine (3 eq.), to a suspension of BEP (1 eq.) in chloroform and stirring at room temperature until a solution forms.



Scheme 3 Comparison of reaction path and reaction outcome between the amine isomers, 2-methyl-4-(3-aminophenyl)thiazole and 2-amino-4-(*p*-tolyl)thiazole.

The use of chloroform as a solvent acts as a visual aid to the end point of the reaction; BEP is sparingly soluble in chloroform and the TIP products are soluble thus providing an indicator as to when the reaction is complete by conversion from a suspension to a solution.[15] A water and brine wash followed by solvent concentration under vacuum yields the crude TIP product, which can be further purified through methanol triturations. However, when the amine responsible for the nucleophilic attack on the α-position of the BEP was in direct conjugation with the electronegative substituents, no TIP was isolated from the reactions under these conditions. ^{1}H NMR studies carried out in both chloroform and methanol revealed phenanthridinium pseudo base formation[17] only (see ESI†).

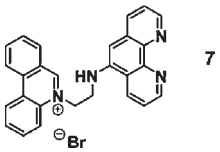
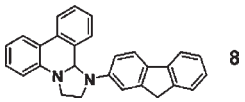
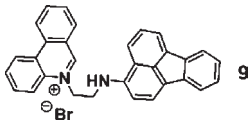
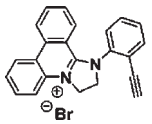
By comparison of 2-methyl-4-(3-aminophenyl)thiazole and its isomer 2-amino-4-(*p*-tolyl)thiazole, it can be seen that simply rearranging the amine structure prevents the TIP from successfully forming. The existence of the tautomeric forms[21–23] is thought to be a contributing factor for those reactions yielding no product. Although the amine form is the predominant tautomer,[24] the presence of the tautomeric equilibrium results in lower nucleophilicity of the amine.[3,25,26]

This implies that the position of the amine in respect to electron withdrawing groups is crucial, and in the unsuccessful attempts to synthesise the TIP, the amine side chain proved to be excessively electron withdrawing, consequently causing the nucleophilic nitrogen to be too weak to attack the α-position of the BEP. Without a nitrogen possessing enough nucleophilicity, the reactive BEP forms a pseudo base structure which can further react/decompose to other undesired byproducts.

Substitution at the *ortho*-position of the amine

The second group of amines chosen (Table 2) show the influence of substituents at the position *ortho* to the amine. 2-ethynylaniline, 3-aminofluoranthene and 5-amino-1,10-phenanthroline were chosen as they displayed a gradual increase in steric bulk at the *ortho*-position when compared to 2-aminofluorene whilst the electronic differences remained close enough to retain the required nucleophilicity of the primary amine. When

Table 2 Selected aryl amines with varying *ortho*-position bulk and the isolated product from reactions using the general chloroform method for TIP synthesis

Amine	Product isolated	% Yield
5-amino-1,10-phenanthroline	 **7**	32
2-aminofluorene	 **8**	90
3-aminofluoranthene	 **9**	53
2-ethynylaniline	 **10**	82

the substituent was simply a proton, the reaction was permitted to proceed as normal and the chloroform reaction method yielded the TIP (**8**) as expected, typically in high yields as can be seen with the reaction using 2-aminofluorene.

However when the substituent at the *ortho*-position increased in size, the TIP was not able to be isolated and in these cases the DIP or singly charged AEP was obtained: With 2-ethynylaniline, the reaction yielded the DIP (**10**), however when the steric bulk at the *ortho*-position was increased further still, as in the cases of both 3-aminofluoranthrene and 5-amino-1,10-phenanthroline, the singly charged AEPs (**7** and **9**) were produced.

Structural analysis of the TIP has indicated that the amine side chain and TIP hydride lie preferentially in a *syn* conformation.[15,17] While bulkier amino substituents have been reported to help stabilise the TIP structure by creating a steric shield for the "hydride" and therefore minimising its transfer, it has been demonstrated here that when the sterics surrounding the nucleophilic nitrogen become too large, this is not the case and formation of the DIP or AEP will be favoured. This is demonstrated here where the slightly bulkier 2-ethynylaniline gave a solution as expected when reacted using the conventional TIP method in chloroform. Upon work-up, the crude product displayed some indication of the TIP structure along with the DIP form by ^{1}H NMR analysis however it was not possible to isolate the TIP itself. It was thought that the TIP persists long enough to be seen by ^{1}H NMR but that the mild strain between the side chain and TIP hydride results in rotation of the amine, 'breaking' the steric shield and allowing oxidation to the DIP structure (**10**). On the other hand, both 3-aminofluoranthene and 5-amino-1,10-phenanthroline never developed a solution when reacted with the BEP under the standard reaction conditions and analysis of the suspensions showed no signs of the TIP, only clean singly charged AEPs (**7** and **9**). Here the initial formation of the intermediate must generate too much strain and the newly formed ring structure reopens almost immediately.

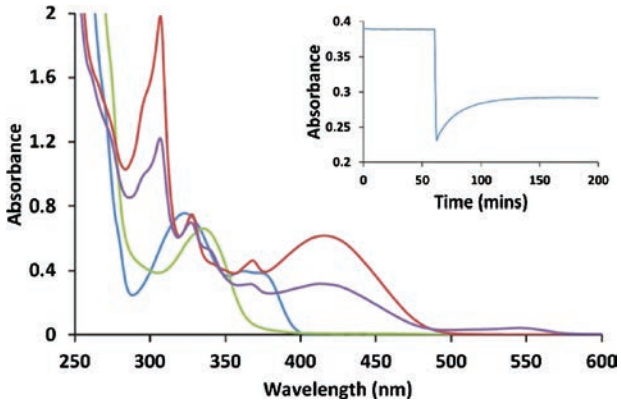


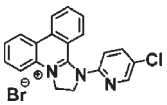
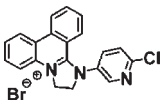
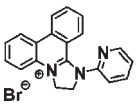
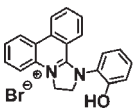
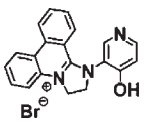
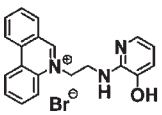
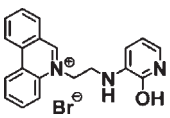
Fig. 1 Spectra for the products, reactants and reaction mixture for the reaction between 0.1 mM BEP solution (2 mL, 1 eq) and 0.1 mM 3-aminofluoranthene and triethylamine solution (2 mL, 1 and 3 eq. respectively) (i) 0.1 mM BEP, blue curve; (ii) 0.1 mM 3-aminofluoranthene, red curve; (iii) product solution after 10 h, purple curve; (iv) 0.05 mM pseudo base, green curve. (Inset) Plot of absorbance changes at 373 nm against time.

Taking into account that some of the experiments showed no indication of the TIP forming when monitored only by ^{1}H NMR, timed UV experiments were carried out to support the proposed mechanism of formation (Fig. 1). Solutions of amine with triethylamine in acetonitrile were mixed and added to BEP to closely mimic the normal reaction conditions; BEP (1 eq.) with amine (1 eq.) and triethylamine (3 eq.). The BEP solution was monitored for an hour and then the basic amine solution was added and the reaction mixture was then monitored for a further 9 h. At 373 nm, the 0.1 mM BEP solution absorbs relatively strongly. On addition of the 3-aminofluoranthene (1 eq.) and triethylamine (3 eq.), the intermediates (pseudo base, alpha-adduct and TIP) are rapidly formed, none of which have an absorbance at 373 nm. The amine itself absorbs weakly at 373 nm, which accounts for the observation that the absorbance does not drop completely to zero upon addition. As the product forms, the ring opens re-establishing the phenanthridinium ring system and the absorbance increases.

For the reaction of the BEP and 2-aminofluorene (see ESI for the UV-vis spectra†), the amine has no absorption at 373 nm, so when the intermediates form upon addition of the 2-aminofluorene and triethylamine, the absorbance drops to zero. However, as the phenanthridinium ring system is not restored only a slight absorbance rise at 373 nm is observed upon conversion to the TIP. The monitored reaction for the DIP formation from BEP and 2-ethynylaniline shows the same initial drop in absorbance at 373 nm (see ESI for the UV-vis spectra†), however not to zero as expected: Initially the absorbance can be attributed to residual BEP, which is then converted to the product mixture. Unfortunately, the absorbances for the reactants and products at 373 nm for this particular reaction are very similar and therefore no change in intensity at this wavelength is observed as the reaction progresses.

While bulkier amino substituents have been reported to help stabilise the TIP structure by creating a steric shield for the "hydride" and therefore minimising its transfer,[15,17] it has been demonstrated here that when the sterics surrounding the nucleophilic nitrogen become too large, this is not the case and formation of the DIP or AEP will be favoured. This is due to the reduced stability of these TIPs favouring further reaction by either oxidation or ring opening: The non-planarity of the TIP structures creates an environment where interaction of the *ortho* substituents with the TIP alpha proton are possible and increased steric bulk at the *ortho*-position therefore leads to greater strain which can be released *via* oxidation to the planar DIP or ring opening to the AEP.

Table 3 Chosen aryl amines and isolated product from reactions using the general method for TIP synthesis

Amine	Product isolated		% Yield
2-amino-5-chloropyridine		**11**	45
5-amino-2-chloropyridine		**12**	15
2-aminopyridine		**13**	29
2-aminophenol		**14**	49
4-hydroxy-3-aminopyridine		**15**	56
2-amino-3-hydroxypyridine		**16**	43
3-amino-2-hydroxypyridine		**17**	65

Effects of neighbouring hydroxyl groups and pyridine nitrogens

Finally, the effects brought about by including a hydroxyl group and/or a pyridyl nitrogen were probed (Table 3). By incorporating a pyridyl ring or an *ortho*-hydroxyl group in the amine substrate, the TIP was not isolated. With 2-amino-5-chloropyridine, 5-amino-2-chloropyridine and 2-aminopyridine, the reactions all developed solutions after stirring at room temperature and after the standard work up of the reaction all showed signs of the TIP as anticipated when analysed by ^{1}H NMR. However none of the TIPs were able to be successfully isolated; instriethylamined, the corresponding DIPs were yielded (**11**–**13**). When a hydroxyl group was introduced into the amines used, the reactions never formed solutions, even after 72 h.

While reactions monitored by ^{1}H NMR showed initial traces of TIP in the case of 2-aminophenol and 4-hydroxy-3-aminopyridine, both of which ultimately yielded DIP structures (**14**

and **15**), ^{1}H NMR studies of 2-amino-3-hydroxypyridine and 3-amino-2-hydroxypyridine revealed no traces of TIP, only the singly charged AEPs (**16** and **17**), which were later isolated. Even though none of the reactions yielded the TIP form and some showed no traces of any TIP formation, all the reactions carried out must have given the intermediate initially, due to the reaction pathway followed (Scheme 1). However in all the cases demonstrated, the TIP is not stable enough under the reaction conditions and is either oxidised to the DIP or the imidazole ring reopens to give the AEP. In the situation where the AEP was isolated, ^{1}H NMR studies showed no TIP at all, indicating that the TIP form was particularly unstable and ring opening was very fast.

The *ortho*-positioning of the hydroxyl alone cannot be attributed to the ring opening of TIPs to AEPs **16** and **17** as DIPs **14** and **15** are also synthesised from an amine with a hydroxyl *ortho* to the nucleophilic amine. Rules regarding the reaction outcome as a function of the relative position of the pyridyl nitrogen cannot be established either and so predicting which route the TIP takes, oxidation or ring opening, to release the strain of the ring system and thus predicting whether the DIP or AEP will be favoured is not possible from the current set of results. However one thing that can be said is that both functionalities appear to have a destabilising effect, making isolation of the corresponding TIP structures unlikely.

Conclusions

In summary, we have presented evidence to support the 3-step reaction mechanism for the reactions of primary amines with BEP, in particular focusing on the influence the amine structure and conformation has on the products isolated: Amines directly conjugated to significantly electron withdrawing groups have been shown to prevent formation of any of the desired structures (TIP, DIP or AEP), whereas when the restricting group is distant from the primary amine, all can be produced. When the aryl amine has greater steric bulk at the *ortho*-position or N-containing aromatic rings such as pyridines, DIP or AEP formation is favoured over that of TIP. This is due to the reduced stability of these TIPs favouring further reaction by either oxidation or ring opening. This heightened knowledge of the influence of the amines environment on this reaction sequence is important since it will allow the rational design of new TIP, DIP and AEP heterocycles. This level of control will aid our future studies in the synthesis and discovery of similar heterocyclic structures formed from more complex and bio-relevant amines, with possible applications in the pharmaceutical industry.

Experimental

Instruments and materials

All starting materials and solvents were commercially available (reagent grade) and were used as supplied, from Sigma-Aldrich and Alfa Aesar Chemical Companies, without further purification. ^{1}H and ^{13}C NMR were recorded on a Bruker DPX 400 spectrometer operating at 400 and 100 MHz, respectively. Chemical shifts (δ) are given in parts per million (ppm) relative to the residual solvent peak. Coupling constants (J) are given in hertz. The multiplicities are expressed as follows: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, brd = broad. All spectra were recorded on Shimadzu FTIR 8400S Fourier Transformer Infrared Spectrophotometer; peaks are quoted in wavenumbers (cm^{-1}) and their relative intensities are reported as follows: s = strong, m = medium, w = weak. UV-vis spectroscopy was performed on a JASCO V-670 Spectrophotometer. Mass spectra were obtained on a JEOL JMS 700 spectrometer operating in fast atom bombardment (FAB), electron ionization (EI), or chemical ionization (CI) mode.

1-Benzothiazol-6-yl-1,2,3,12*b*-tetrahydroimidazo[1,2-*f*] phenanthridine (1)

To a suspension of BEP (700 mg, 1 eq) in chloroform (40 mL) was added 6-aminobenzothiazole (286 mg, 1 eq) and triethylamine (797 μL, 3 eq) and stirred at room temperature for 3.5 h. The orange solution was washed with water, then brine and concentrated under vacuum. The orange honeycomb-like residue was sonicated in methanol then filtered, yielding a pale cream powder (540 mg, 80%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.76 (s, 1H), δ 8.03 (d, 1H, J = 8.8 Hz), δ 7.90 (d, 1H, J = 6.4 Hz), δ 7.81 (d, 1H, J = 7.2 Hz), δ 7.44 (t, 1H, J = 7.6 Hz), δ 7.36 (t, 1H, J = 8 Hz), δ 7.27 (t, 1H, J = 6.4 Hz), δ 7.19 (m, 2H), δ 7.07 (t, 1H, J = 7.2 Hz), δ 7.03 (dd, 1H), δ 6.86 (d, 1H, J = 8 Hz), δ 5.42 (s, 1H), δ 4.19 (m, 1H), δ 3.97 (t, 1H, J = 7.6 Hz), δ 3.72 (t, 1H, J = 7 Hz), δ 3.45 (m, 1H); ^{13}C NMR (DMSO, 100 MHz): δ 151.6 (CH), δ 146.9 (C), δ 145.9 (C), δ 143.1 (C), δ 135.2 (C), δ 133.5 (C), δ 131.6 (C), δ 129.3 (CH), δ 127.8 (CH), δ 127.0 (CH), δ 123.7 (CH), δ 123.6 (CH), δ 123.4 (CH), δ 123.3 (C), δ 122.9 (CH), δ 119.7 (CH), δ 114.8 (CH), δ 113.2 (CH), δ 105.3 (CH), δ 74.6 (CH), δ 51.4 (CH_2), δ 44.4 (CH_2); IR (KBr, cm^{-1}): 3060 (w), 2840 (w), 1595 (m), 1444 (m), 1329 (m), 1198 (m), 817 (s), 746 (s); MS (FAB) for ($C_{22}H_{18}N_3S$) $(M + H)^+$ 356 (100), 193 (100), 180 (40), 154 (28), 136 (28); HRMS (FAB) for ($C_{22}H_{18}N_3S$) calculated 356.1221, found 356.1223.

1-Benzothiazol-6-yl-2,3-dihydro-1*H*-imidazo[1,2-*f*] phenanthridin-4-ylium bromide (2)

To a suspension of BEP (367 mg, 1 eq) in chloroform (25 mL) was added 6-aminobenzothiazole (150 mg, 1 eq) and triethylamine (416 μL), 3 eq) and stirred under nitrogen at room temperature. The resulting solution was washed with water then brine, and then concentrated to remove traces of triethylamine. The residue was dissolved in ethyl acetate and NBS (178 mg, 1 eq) added forming a creamy suspension which was filtered and collected as a peach powder (346 mg, 80%). ^{1}H NMR (DMSO, 400 MHz): δ 9.63 (s, 1H), δ 8.93 (d, 1H, J = 8.4 Hz), δ 8.85 (d, 1H, J = 7.6 Hz), δ 8.62 (d, 1H, J = 2 Hz), δ 8.38 (d, 1H, J = 9.2 Hz), δ 8.05 (t, 1H, J = 7.2 Hz), δ 7.95 (t, 1H, J = 7.2 Hz), δ 7.88 (d, 1H, J = 8.0 Hz), δ 7.87 (d, 1H, J = 8.0 Hz), δ 7.74 (t, 1H, J = 7.6 Hz), δ 7.52 (t, 1H, J = 7.8 Hz), δ 7.31 (d, 1H, J = 8 Hz), δ 5.00 (t, 2H, J = 10.8 Hz), δ 4.68 (m, 2H); ^{13}C NMR (DMSO, 100 MHz): δ 159.2 (CH), δ 153.4 (C), δ 152.8 (C), δ 136.4 (C), δ 135.4 (CH), δ 135.3 (C), δ 135.1 (C), δ 132.6 (C), δ 131.6 (CH), δ 128.8 (CH), δ 127.2 (CH), δ 125.9 (CH), δ 125.0 (CH),

δ 124.9 (CH), δ 124.32 (CH), δ 124.12 (CH), δ 121.20 (CH), δ 120.50 (C), δ 116.3 (CH), δ 115.2 (C), δ 54.7 (CH_2), δ 47.0 (CH_2); IR (KBr, cm^{-1}): 3048 (w), 3028 (w), 1595 (m), 1579 (s), 1304 (m), 1238 (w), 940 (w), 846 (m); MS (FAB) for ($C_{22}H_{16}N_3S$) (M^+) 354 (100), 179 (20), 160 (42), 101 (28), 80 (65), 46 (82), 16 (57); HRMS (FAB) for ($C_{22}H_{16}N_3S$) (M^+) calculated 354.1065, found 354.1063.

1-(1*H*-Benzoimidazol-5-yl)-1,2,3,12*b*-tetrahydroimidazo[1,2-*f*]phenanthridine (3)

To a solution of BEP (700 mg, 1 eq) in methanol (50 mL) was added 5-aminobenzimidazole (254 mg, 1 eq) and triethylamine (797 µL, 3 eq) and stirred at room temperature. An orange solution immediately formed, then after 1 h a peach/orange suspension developed. The suspension was filtered and washed with fresh methanol. Precipitate formed in the methanol filtrate, and was more clean TIP (260 mg, 40%). ^{1}H NMR (DMSO, 400 MHz): δ 12.02 (s, 1H), δ 8.02 (brd, 1H), δ 7.93 (d, 1H, J = 7.6 Hz), δ 7.85 (d, 1H, J = 7.6 Hz), δ 7.50 (brd, 1H), δ 7.40 (t, 1H, J = 7.4 Hz), δ 7.32 (t, 1H, J = 7.4 Hz), δ 7.24 (t, 1H, J = 7.4 Hz), δ 7.04 (d, 1H, J = 7.6 Hz), δ 7.00 (t, 1H, J = 7.4 Hz), δ 6.89 (d, 1H, J = 8 Hz), δ 6.77 (d, 2H, J = 8 Hz), δ 5.26 (s, 1H), δ 4.07 (m, 1H), δ 3.83 (t, 1H, J = 7.6 Hz), δ 3.70 (t, 1H, J = 7.6 Hz), δ 3.32 (hidden under DMSO peak, 1H); ^{13}C NMR (DMSO, 100 MHz): δ 143.4 (C × 2), δ 133.9 (C × 2), δ 131.6 (C × 2), δ 129.3 (CH), δ 127.7 (CH), δ 126.9 (CH), δ 124.2 (CH), δ 123.6 (CH), δ 123.3 (C), δ 123.2 (CH), δ 119.5 (CH), δ 113.0 (CH), δ 75.1 (CH), δ 52.1 (CH_2), δ 44.4 (CH_2); MS (FAB) for ($C_{22}H_{19}N_4$) ($M + H^+$) 338.7 (12), 231 (9), 157 (40), 80 (100); HRMS (1312) (FAB) for ($C_{22}H_{19}N_4$) ($M + H^+$) calculated 339.1610, found 339.1609.

1-(1*H*-Benzoimidazol-5-yl)-2,3-dihydro-1*H*-imidazo[1,2-*f*]phenanthridin-4-ylium bromide (4)

To a suspension of BEP (700 mg, 1 eq) in chloroform (50 mL) was added 5-aminobenzimidazole (254 mg, 1 eq) and triethylamine (797 µL, 3 eq) and stirred at room temperature going to a solution and then to a suspension after 20 min. The suspension was filtered and the residue dissolved in ethyl acetate. NBS (339 mg, 1eq) was added and stirred, creating a murky yellow suspension. This was filtered, washed with diethyl ether and dried. Precipitate had formed in the ethyl acetate filtrate, so this was filtered and dried (429 mg, 54%). ^{1}H NMR (DMSO, 400 MHz): δ 8.90 (d, 1H, J = 8 Hz), δ 8.82 (d, 1H, J = 8 Hz), δ 8.48 (s, 1H), δ 8.02 (t, 1H, J = 7.2 Hz), δ 7.94 (t, 2H, J = 7.4 Hz), δ 7.97 (broad m, 2H), δ 7.71 (t, 1H, J = 7.4 Hz), δ 7.55 (brd, 1H), δ 7.47 (t, 1H, J = 7.8 Hz), δ 7.24 (d, 1H, J = 7.6 Hz), δ 4.96 (t, 2H, J = 10.4 Hz), δ 4.66 (m, 2H); ^{13}C NMR (DMSO, 100 MHz): δ 152.7 (C), δ 144.6 (CH), δ 135.2 (CH × 2), δ 135.0 (C), δ 133.1 (C), δ 132.7 (C), δ 131.5 (CH), δ 128.6 (CH), δ 127.1 (CH), δ 125.6 (CH), δ 124.2 (CH), δ 124.1 (CH × 2), δ 120.5 (CH), δ 120.3 (C), δ 116.1 (CH), δ 115.5 (C), δ 55.1 (CH_2), δ 46.8 (CH_2); IR (Goldengate, cm^{-1}): 3054 (w), 2729 (w), 1774 (w), 1705 (m), 1543 (s), 1312 (m), 1173 (m), 754 (s); MS (FAB) for ($C_{22}H_{17}N_4$) (M^+) 337 (100), 180 (10); HRMS (FAB) for ($C_{22}H_{17}N_4$) (M^+) calculated 337.1453, found 337.1450.

1-[3-(2-Methyl-thiazol-4-yl)-phenyl]-1,2,3,12*b*-tetrahydroimidazo[1,2-*f*]phenanthridine (5)

To a suspension of BEP (500 mg, 1 eq) in chloroform (50 mL) was added 4-(3-Aminophenyl)-2-methylthiazole (259 mg, 1 eq) and Et_3N (569 µL, 3 eq) and stirred at room temperature until a solution formed. The reaction mixture was transferred to a separating funnel and washed with water, brine, dried over $MgSO_4$ and concentrated under vacuum, giving a light brown honeycomb like residue. Repeated methanol triturations with sonication gave a cream coloured powder when filtered (205 mg, 38%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.89 (d, 1H, J = 7.6 Hz), δ 7.80 (d, 1H, J = 7.6 Hz), δ 7.42 (t, 1H, J = 7.4 Hz), δ 7.35 (m, 6H), δ 7.05 (t, 1H, J = 7.5 Hz), δ 6.85 (d, 1H, J = 7.8 Hz), δ 6.70 (d, 1H, J = 7.6 Hz), δ 5.43 (s, 1H), δ 4.17 (q, 1H, J = 8.3 Hz), δ 4.01 (t, 1H, J = 8.2 Hz), δ 3.69 (t, 1H, J = 7.2 Hz), δ 3.41 (q, 1H, J = 8.5 Hz), δ 2.79 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 165.7 (C), δ 155.5 (C), δ 149.1 (C), δ 143.4 (C), δ 135.5 (C), δ 134.2 (C), δ 131.9 (CH), δ 129.4 (CH), δ 129.2 (CH), δ 127.9 (CH), δ 127.3 (CH), δ 124.4 (CH), δ 124.3 (C), δ 123.8 (CH), δ 123.5 (CH), δ 120.0 (CH), δ 116.4 (CH), δ 113.7 (CH), δ 113.0 (CH), δ 112.5 (CH), δ 112.3 (CH), δ 75.0 (CH), δ 51.1 (CH_2), 44.9 (CH_2), δ 19.4 (CH_3); IR (Goldengate, cm^{-1}): 3107 (w), 2875 (w), 2838 (w), 1600 (m), 1446 (m), 1319 (m), 1170 (m), 750 (s); MS (EI^+) for ($C_{25}H_{21}N_3S$) (M) 395.1 (30), 193 (100), 165 (20), 91 (85); HRMS (EI^+) for ($C_{25}H_{21}N_3S$) (M^+) calculated 395.1456, found 395.1458.

1-[3-(2-Methyl-thiazol-4-yl)-phenyl]-2,3-dihydro-1*H*-imidazo[1,2-*f*]phenanthridin-4-ylium bromide (6)

To a suspension of 5-bromoethylphenanthridinium (386 mg, 1 eq) in chloroform (20 mL) was added 4-(3-aminophenyl)-2-methylthiazole (200 mg, 1 eq) and triethylamine (431 µL, 3 eq) and stirred at room temperature under N_2 until a solution formed after 1 h. The reaction mixture was washed with water, brine, dried over $MgSO_4$ and concentrated under vacuum, giving a light brown honeycomb like residue, which was dissolved in ethyl acetate and NBS (186 mg, 1 eq) added and stirred for 2 h and then filtered (480 mg, 96%). ^{1}H NMR (DMSO, 400 MHz): δ 9.14 (d, 1H, J = 16.4 Hz), δ 8.93 (d, 1H, J = 8.0 Hz), δ 8.84 (d, 1H, J = 8.0 Hz), δ 8.21 (d, 1H, J = 7.6 Hz), δ 8.12 (s, 1H), δ 8.05 (t, 1H, J = 7.4 Hz), δ 7.94 (t, 1H, J = 7.6 Hz), δ 7.86 (d, 1H, J = 8.0 Hz), δ 7.73 (m, 3H), δ 7.55 (t, 1H, J = 7.8 Hz), δ 7.39 (d, 1H, J = 8.4 Hz), δ 4.96 (t, 2H, J = 10.2 Hz), δ 4.67 (m, 2H), δ 2.68 (s, 3H); ^{13}C NMR (DMSO, 100 MHz) (only 12 CH): δ 116.2 (C), δ 152.6 (C), δ 152.1 (C), δ 139.8 (C), δ 136.6 (C), δ 135.3 (CH), δ 135.1 (C), δ 132.6 (C), δ 131.6 (CH), δ 131.3 (CH), δ 128.7 (CH), δ 127.2 (CH), δ 127.1 (CH), δ 126.0 (CH), δ 125.8 (CH), δ 124.3 (CH), δ 124.1 (CH), δ 120.4 (C), δ 116.2 (CH), δ 115.7 (C), δ 115.3 (CH), δ 54.4 (CH_2), δ 47.0 (CH_2), δ 18.9 (CH_3); MS (FAB) for ($C_{25}H_{20}N_3S$) (M^+) 394 (91), 232 (62), 179 (20), 158 (100), 138 (20), 81 (100), 80 (33); HRMS (FAB) for ($C_{25}H_{20}N_3S$) (M^+) calculated 394.1378, found 394.1382.

5-[2-([1,10]Phenanthrolin-5-ylamino)-ethyl]phenanthridinium bromide (7)

To a suspension of BEP (752 mg, 1 eq) in chloroform (70 mL) was added 1,10-phenathrolin-5-amine (400 mg, 1 eq) and triethylamine (854 μL, 3 eq) and stirred at room temperature as an orange suspension for 4 days and then filtered as an orange powder (320 mg, 32%). ^{1}H NMR (DMSO, 400 MHz): δ 10.03 (s, 1H), δ 9.20 (m, 1H), δ 9.11 (d, 1H, J = 8.4 Hz), δ 9.05 (d, 1H, J = 4 Hz), δ 8.79 (m, 1H), δ 8.75 (d, 1H, J = 2.8 Hz), δ 8.37 (t, 1H, J = 7.8 Hz), δ 8.33 (m, 2H), δ 8.14 (m, 2H), δ 8.06 (d, 1H, J = 6.8 Hz), δ 8.01 (t, 1H, J = 7.6 Hz), δ 7.65 (q, 1H), δ 7.57 (q, 1H), δ 6.95 (s, 1H), δ 6.73 (t, 1H, J = 6 Hz), δ 5.43 (t, 2H, J = 5.2 Hz), δ 4.12 (m, 2H); 13 C NMR (DMSO, 100 MHz): δ 155. 8 (CH), δ 149.4 (CH), δ 146.2 (C), δ 145.5 (CH), δ 140.8 (C), δ 140.2 (C), δ 138.0 (CH), δ 134.5 (C), δ 133.4 (C), δ 133.3 (CH), δ 132.5 (CH), δ 132.0 (CH), δ 130.3 (CH), δ 130.3 (C), δ 130.2 (CH), δ 129.6 (CH), δ 126.0 (C), δ 125.1 (CH), δ 123.5 (C), δ 123.3 (CH), δ 123.1 (CH), δ 122.2 (CH), δ 121.9 (C), δ 119.8 (CH), δ 99.1 (CH), δ 56.1 (CH2), δ 41.6 (CH2); IR (KBr, cm^{-1}): 3227 (w), 3060 (w), 2936 (w), 1626 (m), 1533 (m), 1163 (m), 838 (m), 759 (s); MS (FAB) for ($C_{27}H_{21}N_4^+$) (M^+) 401 (45), 222 (40), 180 (22), 157 (80), 79 (100); HRMS (FAB) for ($C_{27}H_{21}N_4^+$) (M^+) calculated 401.1766, found 401.1772

1-(9*H*-Fluoren-2-yl)-1,2,3,12*b*-tetrahydroimidazo[1,2-*f*] phenanthridine (8)

To a suspension of BEP (700 mg, 1 eq) in chloroform (70 mL) was added 2-aminofluorene (345.6 mg, 1 eq) and triethylamine (1 mL, excess) and stirred at room temperature for 30 min, when a solution had developed. The solution was washed with water and then brine, then concentrated under vacuum to an orange residue, and a methanol trituration yielded a pale yellow powder (666 mg, 90%). ^{1}H NMR (DMSO, 400 MHz): δ 7.95 (d, 1H, J = 7.6 Hz), δ 7.88 (d, 1H, J = 7.6 Hz), δ 7.75 (m, 2H), δ 7.51 (d, 1H, J = 7.2 Hz), δ 7.44 (t, 1H, J = 7.6 Hz), δ 7.31(m, 2H), δ 7.20 (t, 1H, J = 7.2 Hz), δ 7.03 (m, 2H), δ 6.91 (d, 1H, J = 7.2 Hz), δ 6.76 (d, 1H, J = 7.6 Hz), δ 5.34 (s, 1H), δ 4.03 (m, 1H), δ 3.93 (t, 1H, J = 8 Hz), δ 3.86 (s, 2H), δ 3.72 (t, 1H, J = 7.8 Hz); ^{13}C NMR (DMSO, 100 MHz): δ 148.1 (C), δ 144.4 (C), δ 143.2 (C), δ 142.0 (C), δ 141.6 (C), δ 133.8 (C), δ 131.6 (C), δ 131.5 (C), δ 129.3 (CH), δ 127.7 (CH), δ 126.9 (CH), δ 126.6 (CH), δ 125.0 (CH), δ 124.8 (CH), δ 123.9 (CH), δ 123.6 (CH), δ 123.3 (CH), δ 123.3 (C), δ 120.4 (CH), δ 119.6 (CH), δ 118.6 (CH), δ 113.1 (CH), δ 113.0 (CH), δ 110.9 (CH), δ 74.6 (CH), δ 51.2 (CH_2), δ 44.4 (CH_2), δ 36.5 (CH_2); IR (Goldengate, cm^{-1}): 3057 (w), 2962 (w), 2836 (w), 2766 (w), 1611 (m), 1453 (m), 1210 (m), 711 (s); MS (FAB) for ($C_{28}H_{23}N_2$) ($M + H$)$^+$ 387.5 (16), 232 (32), 179 (21), 157 (71), 80 (100); HRMS (FAB) for ($C_{28}H_{23}N_2$) ($M + H$)$^+$ calculated 387.1861, found 387.1855.

5-[2-(Fluoranthen-3-ylamino)-ethyl]phenanthridinium bromide (9)

BEP (500 mg, 1 eq) was suspended in chloroform (50 mL) and stirred with 3-aminofluoranthene (296 mg, 1 eq) and triethylamine (570 μL, 3 eq) at room temperature for 5 h. The suspension was filtered and washed with acetone (305 mg, 53%). ^{1}H NMR (DMSO, 400 MHz): δ 10.07 (s, 1), δ 9.26 (m, 1H), δ 9.17 (d, 1H, J = 8.4 Hz), δ 8.72 (m, 1H), δ 8.40 (t, 1H, J = 6.8 Hz), δ 8.37 (d, 1H, J = 7.2 Hz), δ 8.15 (m, 2H), δ 8.09 (d, 1H, J = 6.8 Hz), δ 8.03 (t, 1H, J = 7.6 Hz), δ 7.99 (d, 1H, J = 7.2 Hz), δ 7.88 (t, 1H, J = 9.2 Hz), δ 7.87 (d, 2H, J = 8.4 Hz), δ 7.52 (t, 1H, J = 7.6 Hz), δ 7.35 (t, 1H, J = 10.6 Hz), δ 7.27 (t, 1H, J = 7.4 Hz), δ 7.03 (t, 1H, J = 5.8 Hz), δ 6.80 (d, 1H, J = 7.6 Hz), δ 5.39 (t, 2H, J = 4.4 Hz), δ 4.10 (q, 2H); ^{13}C NMR (DMSO, 100 MHz): δ 155.7 (CH), δ 144.9 (C), δ 139.1 (C), δ 138.0 (CH), δ 137.3 (C), δ 135.8 (C), δ 134.5 (C), δ 133.4 (C), δ 132.6 (CH), δ 132.0 (CH), δ 130.3 (CH), δ 130.2 (CH), δ 127.4 (CH), δ 126.0 (C), δ 125.7 (CH), δ 125.1 (CH), δ 125.0 (CH), δ 124.2 (C), δ 123.5 (C X 2), δ 123.3 (CH), δ 123.1 (CH), δ 121.5 (CH), δ 121.2 (CH), δ 120.6 (C), δ 120.4 (CH), δ 120.0 (CH), δ 119.8 (CH), δ 104.4 (CH), δ 56.4 (CH_2), δ 41.8 (CH_2); IR (Goldengate, cm^{-1}): 3397 (w), 3016 (w), 1627 (m), 1533 (m), 1429 (s), 1263 (m), 782 (s); MS (FAB) for ($C_{31}H_{23}N_2$) (M^+) 423 (100), 307 (7), 244 (15), 180 (17); HRMS (FAB) for ($C_{31}H_{23}N_2$) (M^+) calculated 423.1861, found 423.1856.

1-(2-Ethynyl-phenyl)-2,3-dihydro-1*H*-imidazo[1,2-*f*] phenanthridin-4-ylium bromide (10)

To a suspension of BEP (700 mg, 1 eq) in chloroform (50 mL) was added 2-ethynylaniline (217 μL, 1 eq) and triethylamine (797 μL, 3 eq) and stirred at room temperature for 4.5 h when a solution formed. The solution was washed with water and brine then concentrated under vacuum to a dark orange oil. Acetone was added to the oil, initially creating a solution but on standing for 18 h a precipitate formed which was filtered and collected as an orange static powder (624 mg, 82%). ^{1}H NMR (DMSO, 400 MHz): δ 8.97 (d, 1H, J = 6.8 Hz), δ 8.86 (d, 1H, J = 6.4 Hz), δ 8.10 (t, 1H, J = 6 Hz), δ 7.96 (t, 1H, J = 6.2 Hz), δ 7.87 (m, 3H), δ 7.77 (t, 1H, J = 5.6 Hz), δ 7.75 (t, 1H, J = 7 Hz), δ 7.72 (t, 1H, J = 6.2 Hz), δ 7.60 (t, 1H, J = 6.2 Hz), δ 7.21 (d, 1H, J = 6.8 Hz), δ 5.13 (m, 1H), δ 5.04 (m, 1H), δ 4.62 (m, 2H), δ 4.49 (s, 1H); ^{13}C NMR (DMSO, 100 MHz): δ 152.8 (C), δ 140.5 (C), δ 135.7 (CH), δ 134.9 (C), δ 134.4 (CH), δ 132.3 (C), δ 131.7 (CH), δ 130.7 (CH), δ 129.1 (CH), δ 128.1 (CH), δ 126.2 (CH), δ 126.1 (CH), δ 124.5 (CH), δ 124.2 (CH), δ 120.5 (C), δ 120.2 (C), δ 116.6 (CH), δ 115.2 (C), δ 87.7 (C), δ 78.2 (CH), δ 53.3 (CH2), δ 47.3 (CH2); IR (Goldengate, cm^{-1}): 3467 (w), 3130 (w), 1706 (w), 1575 (m), 1524 (s), 1301 (m), 785 (s); MS (FAB) for ($C_{23}H_{17}N_2$) 321.4 (M^+) (100), 319.3 (7), 137.2 (8); HRMS (FAB) for ($C_{23}H_{17}N_2$) (M^+) calculated 321.1392, found 321.1395.

1-(5-Chloro-pyridin-2-yl)-2,3-dihydro-1*H*-imidazo[1,2-*f*] phenanthridin-4-ylium bromide (11)

To a suspension of BEP (500 mg, 1 eq) in chloroform (50 mL) was added 2-amino-5-chloropyridine (175 mg, 1 eq) and triethylamine (570 μL, 3 eq) and stirred at room temperature. The suspension became a solution after 2 h 40 min, and was washed with water, brine then concentrated under vacuum to an orange residue. An acetone trituration yielded a yellow precipitate (251 mg, 45%). ^{1}H NMR (DMSO, 400 MHz): δ 9.51 (brd, 1H),

δ 8.98 (d, 1H, *J* = 6.8 Hz), δ 8.91 (d, 1H, *J* = 6.4 Hz), δ 8.71 (d, 1H, *J* = 2 Hz), δ 8.26 (dd, 1H), δ 8.15 (t, 1H, *J* = 5.8 Hz), δ 7.96 (m, 2H), δ 7.80 (t, 1H, *J* = 6 Hz), δ 7.74 (d, 1H, *J* = 7.2 Hz), δ 7.68 (t, 1H, *J* = 6 Hz), δ 7.55 (d, 1H, *J* = 6.8 Hz), δ 5.05 (d, 2H, *J* = 8 Hz), δ 4.73 (d, 2H, *J* = 8 Hz); ^{13}C NMR (DMSO, 100 MHz): δ 152.6 (C), δ 150.8 (C), δ 148.0 (CH), δ 139.7 (CH), δ 135.9 (CH), δ 135.3 (C), δ 132.2 (C), δ 131.7 (CH), δ 130.9 (C), δ 128.8 (CH), δ 128.2 (CH), δ 126.6 (CH), δ 124.3 (CH), δ 124.2 (CH), δ 121.2 (C), δ 121.0 (CH), δ 116.9 (CH), δ 115.1 (C), δ 52.1 (CH_2), δ 47.7 (CH_2); IR (KBr, cm^{-1}): 3440 (m), 3393 (m), 2975 (m), 2935 (m), 2736 (m), 2674 (m), 2491 (m), 1573 (s), 1304 (s), 1112 (m), 857 (m); MS (FAB) for ($C_{20}H_{15}N_3Cl$) (M^+) 332 (28), 107 (100); HRMS (FAB) for ($C_{20}H_{15}N_3Cl$) (M^+) calculated 332.0955, found 332.0952.

1-(6-Chloro-pyridin-3-yl)-2,3-dihydro-1*H*-imidazo[1,2-*f*] phenanthridin-4-ylium bromide (12)

To a round bottomed flask a solution of BEP (286 mg, 1 eq) and 5-amino-2-chloropyridine (100 mg, 1 eq) with triethylamine (325 μL, 3 eq) and chloroform (25 mL) was added and stirred at room temperature for 4 h. The resulting solution was washed with water and brine and was then concentrated under vacuum to form a red/brown residue. The residue was then triturated in acetone to yield the product as a yellow solid (40 mg, 15%). ^{1}H NMR (DMSO, 400 MHz): δ 8.97 (d, 1H, *J* = 6.8 Hz), δ 8.88 (d, 1H, *J* = 6.8 Hz), δ 8.80 (d, 1H, *J* = 2.4 Hz), δ 8.23 (dd, 1H, *J* = 2.4,7.2 Hz), δ 8.12 (t, 1H, *J* = 6.0 Hz), δ 7.96 (t, 1H, *J* = 6.2 Hz), δ 7.88 (t, 2H, *J* = 8.4 Hz), δ 7.77 (t, 1H, *J* = 6.0 Hz), δ 7.67 (t, 1H, *J* = 6.0 Hz), δ 7.49 (d, 1H, *J* = 6.8 Hz), δ 4.99 (t, 2H, *J* = 8.2 Hz), δ 4.66 (t, 2H, *J* = 8.0 Hz); ^{13}C NMR (DMSO, 100 MHz): δ 153.0 (C), δ 150.4 (C), δ 148.0 (CH), δ 138.0 (CH), δ 136.2 (C), δ 135.6 (CH), δ 135.1 (C), δ 132.3 (C), δ 131.6 (CH), δ 129.1 (CH), δ 127.3 (CH), δ 126.2 (CH), δ 126.1 (CH), δ 124.5 (CH), δ 124.1 (CH), δ 120.8 (C), δ 116.5 (CH), δ 114.9 (C), δ 54.2 (CH2), δ 47.4 (CH2); IR (Goldengate, cm^{-1}): 3019 (w), 1615 (w), 1577 (s), 1544 (m), 1527 (m), 1458 (m), 1451 (m), 1375 (w), 1311 (s), 1176 (w), 1108 (s), 935 (w), 844 (w), 761 (s); MS (FAB): 332 (M^+) (20), 179 (30), 157 (30), 80 (100).

1-Pyridin-2-yl-2,3-dihydro-1*H*-imidazo[1,2-*f*]phenanthridin-4-ylium bromide (13)

To a suspension of BEP (500 mg, 1 eq) in chloroform (50 mL) was added 2-aminopyridine (94 mg, 1 eq) and triethylamine (570 μL, 3 eq) and stirred at room temperature for 4 h, when a solution had formed. It was washed with water, brine and concentrated under vacuum to an orange residue, then an acetone trituration yielded a yellow powder (150 mg, 29%). ^{1}H NMR (DMSO, 400 MHz): δ 8.97 (d, 1H, *J* = 6.4 Hz), δ 8.89 (d, 1H, *J* = 6 Hz), δ 8.65 (d, 1H, *J* = 4 Hz), δ 8.14 (t, 1H, *J* = 6.6 Hz), δ 8.12 (t, 1H, *J* = 6.2 Hz), δ 7.97 (q, 1H), δ 7.94 (t, 1H, *J* = 6 Hz), δ 7.79 (t, 1H, *J* = 5.6 Hz), δ 7.72 (d, 1H, *J* = 6.4 Hz), δ 7.64 (d, 1H, *J* = 4.4 Hz), δ 7.63 (t, 1H, *J* = 2.8 Hz), δ 7.37 (d, 1H, *J* = 6.4 Hz), δ 5.04 (t, 2H, *J* = 8 Hz), δ 4.73 (t, 2H, *J* = 8 Hz); ^{13}C NMR (DMSO, 100 MHz): δ 152.7 (C), δ 152.1 (C), δ 149.7 (CH), δ 140.2 (CH), δ 135.8 (CH), δ 135.2 (C), δ 132.2 (C), δ 131.7 (CH), δ 128.6 (CH), δ 127.9 (CH), δ 126.4 (CH), δ 124.7 (CH), δ 124.3 (CH), δ 124.2 (CH), δ 121.04 (C), δ 120.0 (CH), δ 116.8 (CH), δ 115.2 (C), δ 52.2 (CH_2), δ 47.5 (CH_2); IR (Goldengate, cm^{-1}): 3415 (w), 3061 (w), 1647 (w), 1580 (m), 1309 (m), 1172 (w), 1038 (w), 753 (s); MS (FAB) for ($C_{20}H_{16}N_3$) (M^+) 298 (100), 179 (14), 107 (27); HRMS (FAB) for ($C_{20}H_{16}N_3$) (M^+) calculated 298.1344, found 298.1339.

1-(2-Hydroxy-phenyl)-2,3-dihydro-1*H*-imidazo[1,2-*f*] phenanthridin-4-ylium bromide (14)

To a round bottomed flask a solution of BEP (500 mg, 1 eq) and 2-aminophenol (149 mg, 1 eq) with triethylamine (570 μL, 3 eq) and chloroform (40 mL) was added and stirred at room temperature for 2.5 h. This created a creamy suspension which was filtered and collected to yield the product as a white powder (210 mg, 49%). ^{1}H NMR (DMSO, 400 MHz): δ 10.52 (s, 1H), δ 8.94 (d, 1H, *J* = 8.4 Hz), δ 8.83 (d, 1H, *J* = 8.0 Hz), δ 8.09 (t, 1H, *J* = 7.6 Hz), δ 7.94 (t, 1H, *J* = 7.6 Hz), δ 7.85 (d, 1H, *J* = 8.4 Hz), δ 7.73 (t, 1H, *J* = 7.8 Hz), δ 7.64 (d, 1H, *J* = 8.4 Hz), δ 7.60 (d, 1H, *J* = 7.6 Hz), δ 7.50 (t, 2H, *J* = 9.4 Hz), δ 7.17 (d, 1H, *J* = 8.0 Hz), δ 7.11 (t, 1H, *J* = 7.6 Hz), δ 5.05 (q, 1H, *J* = 10.8 Hz), δ 4.94 (q, 1H, *J* = 10.8 Hz), δ 4.53 (t, 2H, *J* = 10.4 Hz); ^{13}C NMR (DMSO, 100 MHz): δ 153.0 (C), δ 152.9 (C), δ 135.5 (CH), δ 134.7 (C), δ 132.5 (C), δ 131.7 (CH), δ 131.6 (CH), δ 129.0 (CH), δ 128.2 (CH), δ 126.0 (CH), δ 125.8 (CH), δ 125.6 (C), δ 124.3 (CH), δ 124.1 (CH), δ 120.7 (CH), δ 120.2 (C), δ 117.7 (CH), δ 116.3 (CH), δ 115.6 (C), δ 52.9 (CH2), δ 46.7 (CH2); IR (Goldengate, cm^{-1}): 2947 (w), 1613 (w), 1577 (m), 1486 (m), 1449 (w), 1393 (w), 1313 (m), 1240 (w), 1171 (w), 1153 (w), 1118 (w), 993 (w), 872 (w), 785 (w), 747 (s); MS (FAB): 313 (M^+) (15), 157 (60), 80 (100).

1-(4-Hydroxy-pyridin-3-yl)-2,3-dihydro-1*H*-imidazo[1,2-*f*] phenanthridin-4-ylium bromide (15)

To a suspension of BEP (850 mg, 2.32 eq) in chloroform (70 mL) was added 3-amino-4-hydroxypyridine (150 mg, 1 eq) and triethylamine (570 μL, 3 eq) and stirred for 2.5 h. The suspension was filtered and washed with acetone (278 mg, 56%). ^{1}H NMR (DMSO, 400 MHz): δ 8.90 (d, 1H, *J* = 6.4 Hz), δ 8.82 (d, 1H, *J* = 6.4 Hz), δ 8.48 (s, 1H), δ 8.09 (t, 1H, *J* = 6.4 Hz), δ 8.06 (d, 1H, *J* = 6.8 Hz), δ 7.94 (t, 1H, *J* = 5.4 Hz), δ 7.92 (d, 1H, *J* = 6 Hz), δ 7.83 (d, 1H, *J* = 6 Hz), δ 7.73 (t, 1H, *J* = 6 Hz), δ 7.68 (t, 1H, *J* = 6.2 Hz), δ 6.40 (d, 1H, *J* = 9 Hz), δ 5.10 (m, 1H), δ 4.83 (m, 1H), δ 4.59 (m, 1H), δ 4.23 (q, 1H); ^{13}C NMR (DMSO, 100 MHz): δ 171.7 (C), δ 154.0 (C), δ 139.2 (CH), δ 137.9 (CH), δ 135.5 (CH), δ 134.1 (C), δ 132.3 (C), δ 131.5 (CH), δ 129.3 (C), δ 129.1 (CH), δ 126.0 (CH), δ 126.0 (CH), δ 124.1 (CH), δ 124.0 (CH), δ 120.5 (C), δ 117.8 (CH), δ 116.5 (CH), δ 116.1 (C), δ 53.4 (CH_2), δ 46.6 (CH_2); IR (Goldengate, cm^{-1}): 3494 (w), 3056 (w), 2817 (w), 1642 (m), 1579 (s), 1312 (m), 784 (m), 717 (s); MS (FAB) for ($C_{20}H_{16}N_3O$) (M^+) 314 (100), 78 (10), 36 (24); HRMS (FAB) for ($C_{20}H_{16}N_3O$) (M^+) calculated 314.1293, found 314.1289.

5-[2-(3-Hydroxy-pyridin-2-ylamino)-ethyl]-phenanthridinium bromide (16)

To a suspension of BEP (500 mg, 1 eq) in chloroform (50 mL) was added 2-amino-3-hydroxypyridine (112.5 mg, 1 eq) and triethylamine (570 μL, 3 eq) and stirred at room temperature for 20 h, then filtered. A further 89 mg of BEP was added, and then filtered to give the product (230 mg, 43%). ^{1}H NMR (DMSO, 400 MHz): δ 10.07 (s, 1H), δ 9.71 (s, 1H), δ 9.2 (d, 1H, J = 6 Hz), δ 9.14 (d, 1H, J = 6.4 Hz), δ 8.85 (d, 1H, J = 6.4 Hz), δ 8.53 (d, 1H, J = 6.4 Hz), δ 8.39 (t, 1H, J = 6.2 Hz), δ 8.17 (t, 1H, J = 5.8 Hz), δ 8.12 (t, 1H, J = 6 Hz), δ 8.07 (t, 1H, J = 6 Hz), δ 7.23 (d, 1H, J = 2.8 Hz), δ 6.75 (d, 1H, J = 5.2 Hz), δ 6.35 (t, 1H, J = 5 Hz), δ 5.23 (t, 2H, J = 4.4 Hz), δ 3.99 (q, 2H); ^{13}C NMR (DMSO, 100 MHz): δ 155.3 (CH), δ 148.8 (C), δ 139.6 (C), δ 137.8 (CH), δ 136.6 (CH), δ 134.4 (C), δ 133.8 (C), δ 132.6 (CH), δ 131.8 (CH), δ 130.5 (CH), δ 130.1 (CH), δ 125.9 (C), δ 124.8 (CH), δ 123.5 (C), δ 123.0 (CH), δ 120.0 (CH), δ 117.7 (CH), δ 112.1 (CH), δ 57.8 (CH_2), δ 45.6 (CH_2); IR (KBr, cm^{-1}): 3426 (m), 3058 (w), 2960 (w), 2675 (w), 1613 (m), 1504 (m), 1174 (m), 1087 (m), 871 (w), 754 (s); MS (FAB) for ($C_{20}H_{18}N_3O$) (M^+) 316 (100), 195 (9), 183 (23), 107 (13); HRMS (FAB) for ($C_{20}H_{18}N_3O$) (M^+) calculated 316.1450, found 316.1446.

5-[2-(2-Hydroxy-pyridin-3-ylamino)-ethyl]phenanthridinium bromide (17)

To a suspension of BEP (500 mg, 1 eq) in chloroform (50 mL) was added 3-amino-2-hydroxypyridine (150 mg, 1 eq) and triethylamine (570 μL, 3 eq) and stirred for 3.5 h. The suspension was filtered and washed with acetone (349 mg, 65%). ^{1}H NMR (DMSO, 400 MHz): δ 11.35 (s, 1H), δ 10.04 (s, 1H), δ 9.21 (d, 1H, J = 5.2 Hz), δ 9.16 (d, 1H, J = 6.4 Hz), δ 8.69 (d, 1H, J = 7.2 Hz), δ 8.56 (d, 1H, J = 6 Hz), δ 8.42 (t, 1H, J = 5.8 Hz), δ 8.13 (m, 3H), δ 6.62 (brd, 1H), δ 6.37 (t, 1H, J = 5.6 Hz), δ 6.03 (t, 1H, J = 5.4 Hz), δ 5.92 (t, 1H, J = 5.4 Hz), δ 5.20 (t, 2H, J = 4.4 Hz), δ 3.78 (q, 2H); ^{13}C NMR (DMSO, 100 MHz): δ 157.3 (C), δ 155.6 (CH), δ 137.9 (CH), δ 137.7 (C), δ 134.5 (C), δ 133.5 (C), δ 132.8 (CH), δ 131.9 (CH), δ 130.3 (CH), δ 130.2 (CH), δ 125.9 (C), δ 124.94 (CH), δ 123.5 (C), δ 123.1 (CH), δ 119.9 (CH), δ 119.8 (CH), δ 107.2 (CH), δ 105.9 (CH), δ 56.1 (CH_2), δ 41.2 (CH_2); IR (KBr, cm^{-1}): 3280 (w), 2985 (w), 1726 (w), 1627 (m), 1448 (m), 1259 (m), 1128 (m), 749 (s); MS (FAB) for ($C_{20}H_{18}N_3O$) (M^+) 316 (53), 183 (18), 151 (17), 114 (14), 78 (53), 61 (100), 38 (36), 36 (26); HRMS (FAB) for ($C_{20}H_{18}N_3O$) (M^+) calculated 316.1450, found 316.1446.

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