Chlorins with an exocyclic δ-lactone ring and their derivatives

Andrei F. Mironov,*[a] Aleksei V. Efremov,[a] Olga A. Efremova,[a] Raymond Bonnett *[b] and Gabriel Martinez[b]

[a] *M.V. Lomonosov State Academy of Fine Chemical Technology, 117571 Moscow, Russian Federation*
[b] *Chemistry Department, Queen Mary and Westfield College, University of London, London, UK E1 4NS*

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Two novel reactions are described in the series of di- and tetra-hydroporphyrins possessing an exocyclic six-membered anhydride ring. In the first reaction, the partial reduction of the anhydride ring of bacteriopurpurin and of two purpurins with sodium borohydride gave δ-lactones, which had considerable stability towards acidic and basic cleavage. The partial reduction showed regioselectivity, which was especially pronounced with bacteriopurpurin. In the second reaction, the attempted dehydrogenation with DDQ of chlorins possessing a free propionic acid residue at C-17 (purpurin 18 and its 3-acetyl-3-devinyl analogue) led to intramolecular cyclisation to give products with a δ-lactone ring fused to the β-face of ring D. In this case the lactone ring could be opened to give the 18-hydroxy-chlorins, the dehydration of which yielded the corresponding porphyrins (purpuroporphyrins, retaining the exocyclic anhydride ring).

Introduction

Recently interest has been aroused in natural chlorins and their derivatives which contain an additional exocyclic ring in the lower part (rings C and D) of the macrocycle.[1] Thus 13^2,17^3-cyclopheophorbide enol has been isolated from the sponge *Darwinella oxeata*,[2] and in marine animals such as the short-necked clam, *Ruditapes philippinarum*, a novel class of chlorin with antioxidant activity has been discovered.[3,4] These chlorins, which presumably arise by modification of ingested chlorophyll *a*, appear to protect the animals against damage by reactive oxygen species. It is interesting that the compound, chlorophyll *a*, involved in photosynthesis and oxygen production in the plant kingdom is so closely related to compounds which appear to be used as protective antioxidants in marine animals.

A second group of such compounds, purpurin 18 and its derivatives possessing a six-membered anhydride ring encompassing C-13, C-14 and C-15, is now being actively examined for sensitising activity in photodynamic therapy.[5,6] Additional interest in these chlorins arises because of new chemistry involving modifications of these rings and substituents in these rings.[7] A special role in these transformations is played by the propionic acid residue at C-17, which can be cyclised onto the cyclopentanone ring to give a new seven-membered ring as in the natural 13^2,17^3-cyclopheophorbide *a* enol.[8,9]

In the course of systematic studies on the chemistry of chlorins and bacteriochlorins with a conjugated six-membered anhydride ring,[10] we have found novel reactions leading to two new series of compounds possessing a δ-lactone ring.[11,12]

Lactones at the isocyclic ring position

The first reaction was encountered during the reduction of bacteriopurpurin **1** with sodium borohydride (Scheme 1).

Instead of the hypsochromic shift of the major band (λ_{max} 818 nm) by 25–30 nm expected for the reduction of 3-$COCH_3$ to 3-$CHOHCH_3$, the compound obtained showed an intense absorption band (Band I) at λ_{max} 724 nm. It was obvious that such a significant change could not be due merely to the replacement of the acetyl group by the α-hydroxyethyl substituent. Indeed, the subsequent study showed that sodium borohydride reduces not only the acetyl group, but also the anhydride ring to the δ-lactone. Esterification with diazomethane and separation on silica afforded the product **2** in 45% yield. Because of the new chiral centre at C-3^1 this is expected to be a mixture of diastereoismers, but they could not be distinguished. (The same observation applies to **4c** and to **5c** below.)

The ^{252}Cf mass spectrum of the product showed a molecular ion at *m*/*z* 584 and an intense cleavage peak at *m*/*z* 566, which corresponded to elimination of water. From the accurately measured *m*/*z* value of the molecular ion in the FAB mass spectrum it was deduced that the molecular formula of compound **2** was $C_{34}H_{40}N_4O_5$.

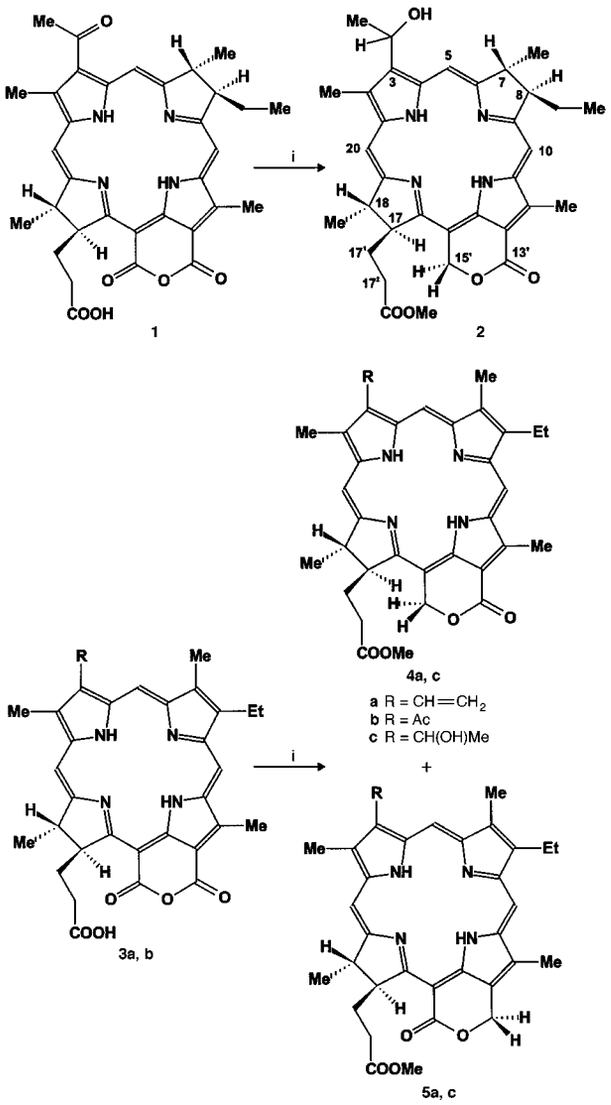
The structure of **2** was established by ^{1}H NMR spectroscopy (Table 1). NOESY spectra were used to obtain spatial relationships in the usual way. The final assignments were made on the basis of NOE correlations (Fig. 1).

Compared to the ^{1}H NMR spectrum of bacteriopurpurin **1**, the spectrum of compound **2** had new signals at δ 6.54 and 6.59. Another difference was that the signal assigned to 17-H was shifted upfield by 1.4 ppm. The spectrum of compound **2** had a characteristic spin system, which corresponded to the $CH_3CH(OH)$ group. The signals of this group were used as the starting point for assignment. Following the usual correlation procedure, all the proton resonances in compound **2** were assigned (Table 1, Fig. 1). The signal of 17-H had NOE cross peaks with 17^1-CH_2 (δ 1.93), 18-CH_3 (δ 1.64) and the CH_2 of the lactone (δ 6.54 and 6.59). Moreover, the resonance of the lactone CH_2 group had a NOE cross peak only with 17-H and CH_2 protons on the propionate chain (δ 1.93 and 2.32). This provides strong evidence that the CH_2 of the lactone is located at position 15, as shown in structure **2**. Formation of a second isomer during the reduction of **1** was not observed.

Treatment of purpurin 18 **3a** with sodium borohydride also resulted in the reduction of the anhydride ring. However, in this case reduction was less regioselective. TLC on silica showed two products in a 3 : 1 ratio. Separation and purification of these isomers was performed by reverse phase HPLC, eluting with CH_3CN–H_2O (10 : 1). The major component was eluted first,

Table 1 Selected ^{1}H NMR spectral data

	Compound							
Proton	**1**	**2**	**3a**	**3b**	**4a**	**5a**	**4c**	**5c**
5-H	9.53 s	8.70 d	9.35 s	9.84 s	9.53 s	9.62 s	9.74 d	9.96 d
10-H	9.00 s	8.48 s	9.58 s	9.53 s	9.70 s	9.71 s	9.62 s	9.58 s
20-H	8.87 s	8.22 s	8.56 s	8.68 s	8.69 s	8.88 s	8.62 s	8.84 s
13^1-CH_2	—	—	—	—	—	6.46 br s	—	6.36 d, 6.39 d
15^1-CH_2	—	6.54 d, 6.59 d	—	—	6.82 s	—	6.73 d, 6.76 d	—
17-H	5.45 d	4.09 dd	5.18 dd	5.20 dd	4.36 dd	5.42 dd	4.29 dd	5.42 dd
18-H	4.49 q	4.18 q	4.38 q	4.42 q	4.48 q	4.47 q	4.43 q	4.43 q
12-CH_3	3.73 s	3.56 s	3.77 s	3.57 s	3.87 s	3.47 s	3.81 s	3.30 s
18-CH_3	1.77 d	1.64 d	1.72 d	1.75 d	1.75 d	1.79 d	1.70 d	1.78 d



Scheme 1 Transformation of bacteriopurpurin and purpurins into δ-lactones. *Reagents and conditions*: i, $NaBH_4$, pyridine, propan-2-ol, 20 °C, 2 h; HCl; CH_2N_2.

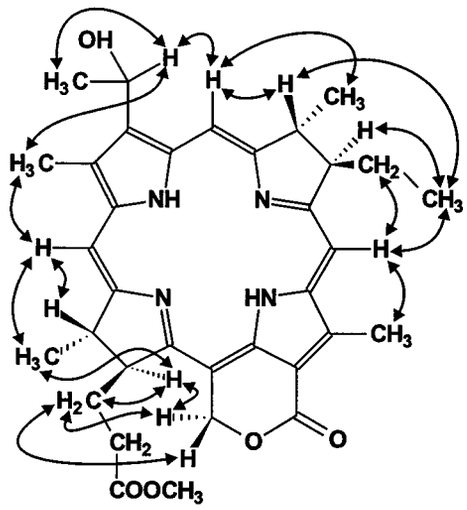


Fig. 1 NOE relationships from the ^{1}H NMR NOESY spectrum of **2**.

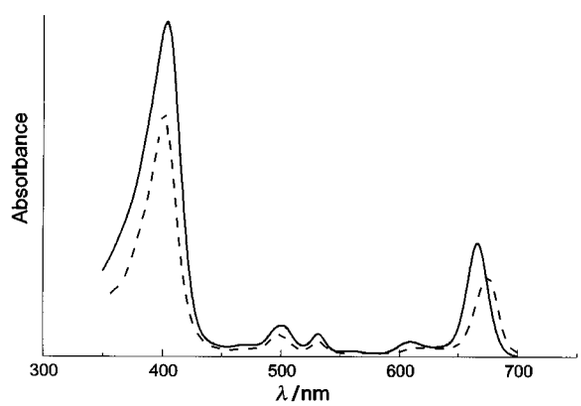


Fig. 2 Electronic absorption spectra of the isomers **4a** (solid line) and **5a** (dashed line).

followed by the minor component. On TLC on silica these products showed the reverse chromatographic mobilities. Both compounds had intense molecular ion peaks $[M + H]^+$ at *m*/*z* 565.3 in their ^{252}Cf mass spectra. High precision FAB mass spectrometry of the major isomer gave an ion at *m*/*z* 565.2802, corresponding to a formula $C_{34}H_{36}N_4O_4$ + H (which requires *m*/*z* 565.2815).

The electronic absorption spectra of these two compounds, although similar in general appearance, showed some differences, as illustrated in Fig. 2. The major isomer had λ_{max} 666 nm (Band I) and the Soret band was at λ_{max} 404 nm, while the minor product showed values of λ_{max} 674 and 397 nm, respectively.

For the ^{1}H NMR spectrum of the major isomer, the signals of the vinyl group were chosen as a starting point in the interpretation of the NOESY results (Fig. 3). The signal of 3^1-CH at δ 8.02 showed a strong NOE cross peak with the *meso*-proton at δ 9.53; one of the protons of 3^2-CH_2 at δ 6.34 also interacted with this *meso*-proton. Hence, the singlet at δ 9.53 was assigned to 5-H. The signals of the vinyl group also interacted with the three-proton singlet at δ 3.45, hence this singlet was assigned to 2-CH_3. Using the singlet of 5-H, the resonance of 7-CH_3 was found, followed by the signals of the ethyl group, which interacted with a singlet at δ 9.70 (10-H). Similarly, a singlet at δ 3.87 was assigned to 12-CH_3. The interactions of a signal of the lactone CH_2 group at δ 6.82 were of crucial importance in assigning structure: strong NOE cross peaks with 17-H (δ 4.36)

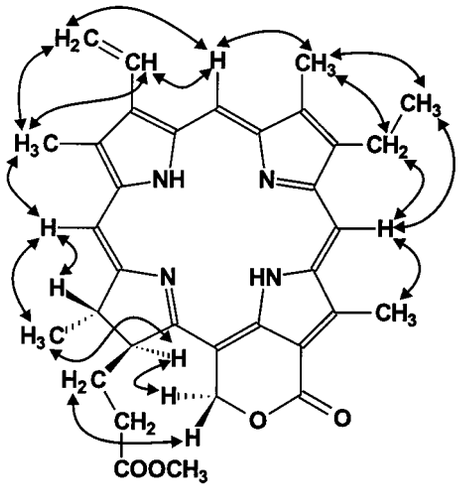


Fig. 3 NOE interactions from the ^{1}H NMR NOESY spectrum of **4a**.

and 17^1-CH_2 (δ 2.01 and 2.46) were observed. We concluded that in this isomer the CH_2 group occupies the 15^1-position, that is, the major isomer was formulated as **4a**.

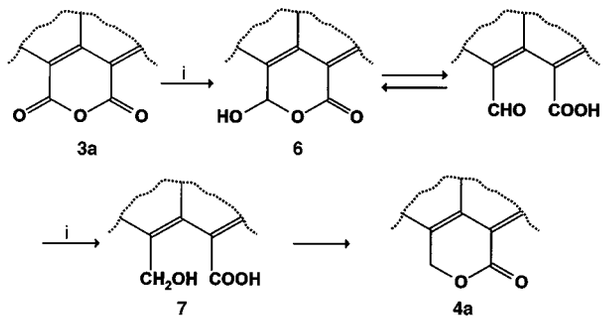
The minor isomer, therefore, has the structure **5a**. The main differences in its ^{1}H NMR spectrum are in the variations of the values of chemical shifts of the lactone CH_2 group (δ 6.46), 17-H (δ 5.42) and 12-CH_3 (δ 3.47) (Table 1).

We also examined the reduction of 3-acetyl-3-devinylpurpurin 18 **3b**. The reaction proceeded similarly to that of the purpurin **3a** and, again, two isomers **4c** and **5c** were observed. However, their separation was even more difficult, due to very similar R_f values. The purified fraction of the lactone mixture contained isomers in a ratio of 3 : 2 as judged from the ^{1}H NMR spectrum. The major isomer, which was isolated by HPLC, had structure **4c**. The lactone methylene group had characteristic signals at δ 6.73 and δ 6.76, the 17-H proton appeared at δ 4.29 and the signal of the methyl group at position 12 was at δ 3.81. The other isomer **5c** showed these signals at δ 6.36 and 6.39, 5.42 and 3.30, respectively.

As can be seen from Table 1, there are general regularities in the ^{1}H NMR spectra of the 15^1-CH_2 lactones **2**, **4a** and **4c** on the one hand, and the 13^1-CH_2 lactones **5a** and **5c** on the other hand. The former group has the signal of the 17-H proton shifted upfield (in the range δ 4.09–4.36), while the latter group has this signal at considerably lower field (δ 5.42). The second difference refers to the chemical shift of 12-CH_3 in the chlorin compounds **4** and **5**. The first series of lactones has δ 3.56–3.87, while the second group shows δ 3.30–3.47. The effect of the lactone carbonyl group on the other substituents is less pronounced.

A characteristic feature of the δ-lactones obtained here is the hypsochromic shift of the visible spectrum with respect to the starting material, which is attributed principally to the removal of conjugation from the system. This is most marked for the change **1**→**2**, with the reduction of both the C-3 acetyl group and the C-15 carbonyl, and here the hypsochromic shift is greatest (Band I: λ_{max} 818→727 nm). Reduction of the purpurins (**3a**, **3b**) at the C-13^1 carbonyl gave products with band I at about λ_{max} 674 nm (**5a**), while reduction at C-15^1 gave products with band I at somewhat shorter wavelengths (**4a**, λ_{max} 666 nm; **4c**, λ_{max} 659 nm). Compound **4a** is a known substance ("chlorin *k*") having been obtained in the 1930s both by Conant[13] and by Fischer[14,15] as a byproduct in the oxidation of chlorin e_6. The reported spectroscopic data (ε_{max} 665.1 > 498.5 > 529.8 > 607.8 nm in pyridine–ether) are consistent with respect both to wavelengths and relative intensities with those observed here (in chloroform).

Another feature of these δ-lactones is their stability towards ring opening: it was not possible to isolate the hydroxy acids



Scheme 2 Presumed mechanism for the reduction of the anhydride ring of purpurins, illustrated for purpurin 18 **3a**. *Reagents*: i, $NaBH_4$.

after either acid or base treatment. Presumably if formed, the hydroxy acid readily recyclises on work up, the driving force for the closure being the diminution of peripheral overcrowding.[16]

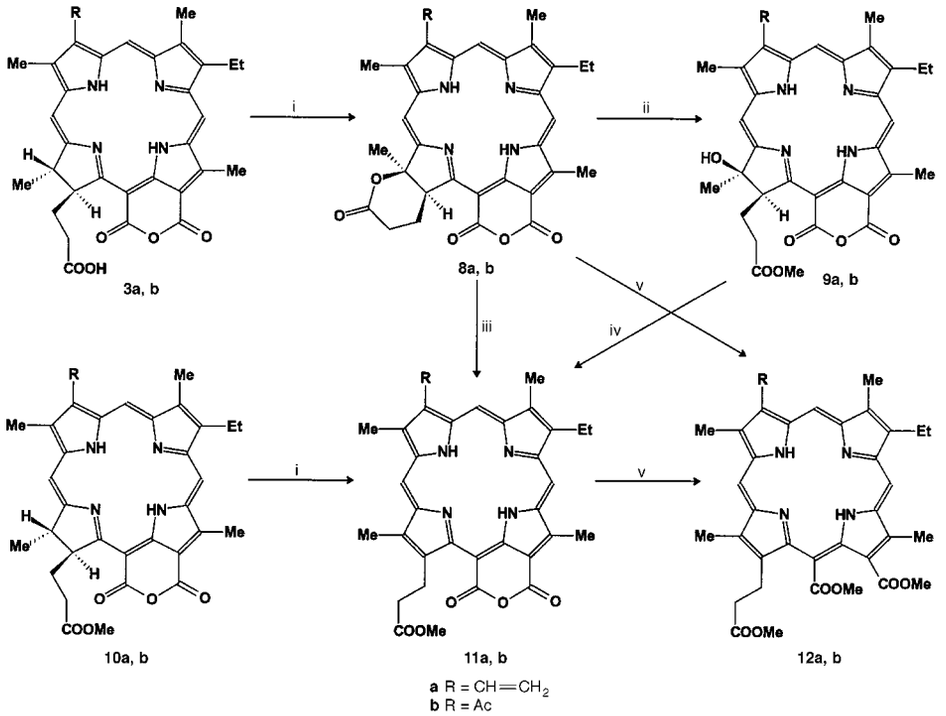
The reduction of the anhydride ring with sodium borohydride demonstrates distinct regioselectivity. It seems that the hydrogenated ring D favours predominant attack of the hydride ion at the neighbouring carbonyl group to give the 15^1-CH_2 lactones. The effect is most pronounced in bacteriopurpurin **1** and less noticeable in purpurins **3a**,**b**. Bailey and Johnson,[17] who were the first to report that sodium borohydride can reduce a cyclic anhydride, found that reduction occurred preferentially at the carbonyl group adjacent to the most substituted carbon atom. This preference for the borohydride reduction of cyclic anhydrides at the most overcrowded carbonyl has been interpreted in terms of the Bürgi–Dunitz trajectory of the approaching nucleophile.[18] On the basis of this, we presume that the mechanism of our purpurin reduction can be described as shown in Scheme 2.

We suppose that initially sodium borohydride attacks the most hindered (15^1) carbonyl group to give **6** [which in the chlorophyll *a* series is a known substance, chlorin 5 (3^1,3^2-didehydro-15-hydroxymethylrhodochlorin δ-lactone)].[16] Borohydride reduction of the open chain form of **6** then gives the 15-hydroxymethyl derivative **7**, which cyclises to the δ-lactone. In support of this proposal, reduction of chlorin 5 with sodium borohydride under the conditions described here gave a product indistinguishable (TLC, UV-VIS) from the δ-lactone **4a**.

Lactones fused at the β,β′ bond of ring D

The second novel reaction,[12] which also affords δ-lactones, is based upon the oxidation of purpurins **3a** and **3b** with 2,3-dichloro-5,6-dicyanobenzoquinone (DDQ). DDQ is one of the most widely used reagents for the dehydrogenation of both synthetic and naturally-occurring chlorins to give porphyrins.[19] Thus, treatment of pheophorbide *a* methyl ester with DDQ results in 2-vinylpheoporphyrin a_5 dimethyl ester.[20] We planned to dehydrogenate purpurins **3a** and **3b** to give the corresponding porphyrins with the six-membered anhydride ring, and then to reduce these with sodium borohydride to the corresponding δ-lactones. The relative amounts of 13^1-CH_2 and 15^1-CH_2 lactones obtained would have made it possible to estimate the influence of the hydrogenation level of ring D on the regioselectivity of the reaction.

We had already prepared one of the required porphyrins.[21] On dehydrogenation of bacteriopurpurin **1** we could isolate either purpurin **3b** or the corresponding porphyrin, depending on the amount of DDQ used and the duration of the oxidation. We would like to emphasise the unusual electronic absorption spectra of porphyrins (purpuroporphyrins) with a conjugated six-membered anhydride ring.[21] The spectrum possesses a strong band at λ_{max} 660 nm, which is usually regarded as characteristic of chlorins, and a series of peaks, of diminishing intensity, at about 620, 560 and 520 nm (*e.g.* **11a** in Fig. 5). Thus, the spectral pattern can be termed the 'retro etio-type', and appears



Scheme 3 Transformation of purpurins into lactonopurpurins and purpuroporphyrins. *Reagents and conditions*: i, DDQ, $CHCl_3$,; ii, TFA, CH_3OH, 2 h; iii, TFA, CH_3OH, 24 h; iv, TFA; v, NaOH, CH_3OH, HCl, CH_2N_2.

to be associated with significant strain in these macrocycles. Analogous observations have been reported very recently by Smith and co-workers.[22]

Scheme 3 outlines the pathways of chemical transformations of purpurin 18 **3a** and its 3-acetyl analogue **3b**. In contrast to the methyl ester of purpurin 18 **10a**, which is readily dehydrogenated with DDQ to give the corresponding porphyrin (purpuroporphyrin 18 methyl ester **11a**), purpurin 18 itself enters into a series of more intricate transformations. Under the same conditions, instead of a porphyrin a new chlorin was formed, which showed λ_{max} 697 nm, and a considerably higher R_f value (silica gel) compared to that of the starting purpurin. The mass spectrum indicated that the new product had a molecular weight two units lower than that of purpurin 18. Accurate measurement of the molecular ion (FAB mode) gave *m*/*z* 563.2297, corresponding to $C_{33}H_{30}N_4O_5$ + H.

Further comparison showed that the ^{1}H NMR spectrum did not contain a quartet at δ 4.38 (1H) and doublet at δ 1.72 (3H) ascribed to the 18-$CHCH_3$ fragment of **3a**, but had a new singlet at δ 2.17 (3H). We concluded from this that the position 18 now lacked a proton, but a quaternary methyl group had been generated. The product was therefore formulated as the δ-lactone **8a** resulting from oxidative intramolecular condensation at C-18 of the propionic acid residue.

Oxidation of purpurin 18 with DDQ under more forcing conditions gave not only lactone **8a** but also the purpuroporphyrin 18. However, in this case the reaction proceeded considerably more slowly than with the methyl ester **10**.

Similarly, 3-acetyl-3-devinylpurpurin 18 **3b** gave the lactone **8b**. The most important ^{1}H NMR data of these compounds are summarised in Table 2.

The absolute configuration of the δ-lactone ring of **8a** was proved using 1D NOE difference ^{1}H NMR spectra. This technique makes it possible to determine the substituents situated at a distance not greater than 5 Å.

At the first stage, in order to find the signal of 18-CH_3 (Fig. 4), the signal at δ 8.82 of the 20-*meso*-proton was used. Responses obtained at δ 2.17 and 3.39 we assigned to methyl groups at positions 18 and 2. Irradiation at the frequency of 18-CH_3 gave the reverse response from 20-H and from the signal of 17-H at δ 5.59. In turn, the frequency of 17-H caused a response from 18-CH_3 and from one of the protons of the 17^1-CH_2 group (δ 2.99). Thus, it was demonstrated that 17-H and 18-CH_3 substituents are located on the same side of the plane of the macrocycle and, therefore, provided that the configuration at C-17 did not change during the reaction, the δ-lactone ring is positioned above the plane as shown in Scheme 3. Similarly, using the 1D NOE difference ^{1}H NMR technique, chemical shift values for the other substituents were found (Table 2).

Often in porphyrin chemistry infrared spectroscopy plays a minor role, but nevertheless the presence of a cyclic anhydride unit deserves attention. The infrared spectra of cyclic six-membered anhydrides show two carbonyl stretching bands (*e.g.* glutaric anhydride, 1802 and 1761 cm^{-1}).[23] These are lowered by aromatic conjugation: for example,[24] 2-oxobenzanthrene-5,10-dicarboxylic anhydride has 1770 and 1736 cm^{-1}. The exocyclic anhydride ring in the purpurin 18 series studied here shows lower values still. Thus purpurin 18 methyl ester **10a** shows ν_{max} 1743, 1727 and 1702 cm^{-1}. In this case all three carbonyl groups may be said to be represented by separate absorption peaks, but in most of the compounds described here these bands overlap. However all the substances with an exocyclic six membered anhydride ring have an absorption band in the region 1743–1755 cm^{-1}. The stretching mode of the conjugated methyl ketone at C-3 appears at about 1660 cm^{-1} in **8b**, **9b** and **11b**.

The mechanism of oxidative lactonisation is thought to involve electron transfer to DDQ, hydrogen ion loss, and a second electron transfer to give a carbocation at C-18, followed by the nucleophilic cyclisation of the free 17-carboxylic acid residue. Analogous oxidative cyclisations are well known in the corrinoid series, where γ-lactone formation is observed.[25]

A study of the chemical reactivity of the lactones revealed their ability to give both porphyrins and, remarkably, the intermediate 18-hydroxy substituted chlorins **9a** and **9b**. Hydroxy products were obtained by brief treatment of the lactones with TFA in methanol. As expected, the hydroxychlorins showed considerably lower chromatographic mobilities on silica (compared to those of the starting lactones) and possessed absorption spectra characteristic of chlorins (Fig. 5). Mass spectrometry provided additional evidence for the methanolysis

Table 2 Characteristic data of ^{1}H NMR purpurin δ-lactones and their derivatives

	Compound					
Proton	**8a**	**8b**	**9a**	**9b**	**11a**	**11b**
5-H	9.53 s	10.18 s	9.34 s	10.00 s	9.43 s, 9.30 s	10.35 s
10-H	9.64 s	9.73 s	9.57 s	9.70 s		9.36 s
20-H	8.82 s	9.00 s	8.80 s	9.00 s	8.95 s	8.85 s
17-H	5.59 dd	5.62 dd	5.30 dd	5.38 dd	—	—
18-CH_3	2.17 s	2.18 s	1.83 s	1.85 s	3.28 s	3.53 s
18-OH	—	—	4.85 s	4.80 s	—	—
2-CH_3	3.39 s	3.63 s	3.28 s	3.30 s	3.33 s	3.53 s
7-CH_3	3.19 s	3.17 s	3.16 s	3.19 s	3.20 s	3.28 s
17^1-CH_2	2.30 m, 2.99 m	2.23 m, 2.98 m	2.61 m	2.60 m	3.88 t	3.88 t
17^2-CH_2	1.63 m, 2.48 m	2.23 m, 2.49 m	2.29 m	2.26 m	3.10 t	3.05 t
12-CH_3	3.75 s	3.70 s	3.77 s	3.83 s	3.52 s, 3.43 s	3.72 s
17^5-CH_3	—	—	3.33 s	3.57 s		3.60 s

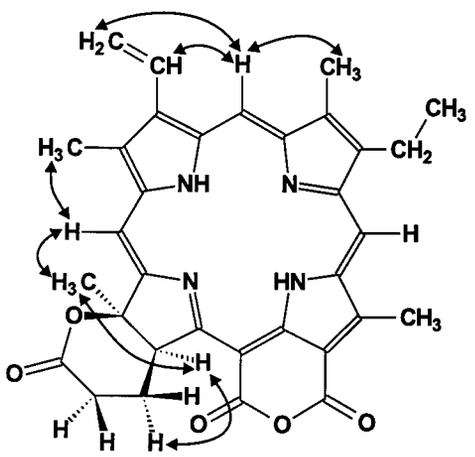


Fig. 4 Data of 1D NOE difference ^{1}H NMR spectra of lactone **8a**.

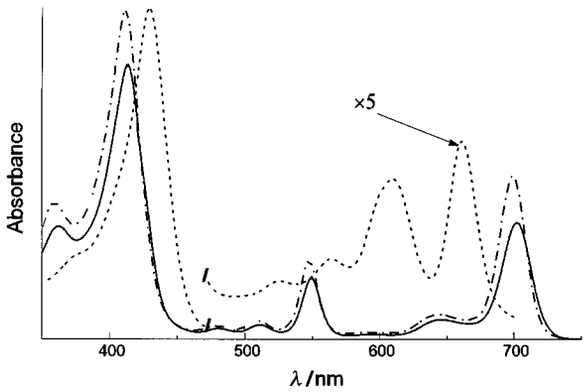


Fig. 5 Electronic absorption spectra of purpurin lactone **8a** (solid line), 18-hydroxypurpurin **9a** (dashed line) and porphyrin **11a** (dotted line, retro-etio spectrum).

of the lactone ring. Signals from the hydroxy group and 18-CH_3 in the ^{1}H NMR spectrum (Table 2) support the structural assignment.

The absolute configuration of the substituents on ring D was proved as before using the 1D NOE difference ^{1}H NMR technique. It was found that 18-Me and 17-H are positioned below the plane of the macrocycle as shown in Scheme 3.

Prolonged treatment of the lactones **8a** and **8b** with TFA in methanol resulted in dehydration, giving purpuroporphyrins **11a** and **11b** respectively. These porphyrins can also be obtained from the hydroxychlorins **9** by treatment with acid. The electronic absorption spectrum of porphyrin **11a** (Fig. 5) is analogous to that of the porphyrin **11b** prepared earlier.[21] The presence of the anhydride ring appears to cause additional strain in the macrocycle, and possibly due to this such porphyrins proved to be unstable. Attempts to carry out reductions with sodium borohydride were not successful.

The lactone ring of **8a** and **8b** can also be opened with sodium hydroxide in methanol. In this case, presumably during the isolation, the chlorin becomes oxidised to the porphyrin. However, porphyrins **12a** and **12b** can be more easily prepared from the purpuroporphyrins **11a** and **11b**.

A striking feature of the ^{1}H NMR spectra of **11a** and **11b** in deuteriochloroform was the unusually high field position of the imino signals (**11a**: δ −5.15, −5.78; **11b**: δ −5.45, −6.18). These signals were also very broad. In porphyrins, NH signals are seldom encountered at such high field, but 3,8-dicarboxydeuteroporphyrin tetramethyl ester does provide an example[26] where the NH protons appear as a broad signal at δ −5.94 (60 Mz). As Janson and Katz[27] have emphasised, in the quoted example this cannot be due to the effect of a simple ring current change, since both *meso* and imino signals are shifted upfield (with respect to deuteroporphyrin dimethyl ester), and a similar circumstance applies here. The phenomenon is being examined further: we suspect that it may arise by a dynamic intermolecular interaction between the carbonyl group(s) of the anhydride (which are likely to be more or less coplanar with the porphyrin ring of **11**) and the imino protons of a second molecule.

Summarising, in this study two unusual series of chlorins with an exocyclic δ-lactone ring have been synthesised. The position of the lactone ring greatly affects the properties of the chlorins. The δ-lactones conjugated with ring C and the 15-*meso* position show stability in alkali and acid media. On the contrary, the δ-lactone at the reduced pyrrole ring D is readily opened in the presence of bases and acids. In the last case an intermediate 18-hydroxy derivative has been isolated, which may be of interest for the synthesis of charge-transfer models and sensitisers for the phototherapy of cancer.

Experimental

General

The following spectroscopic equipment was used. ^{1}H NMR spectra were obtained in $CDCl_3$ on (a) Bruker MSL 200; (b) Varian XR 400 (NOESY spectra, SW = SW^2 = 4545.5 Hz; NP 1024; NI 256, mix 0.5 s); (c) Bruker AMX 600; COSY and NOESY spectra were recorded in a phase-sensitive absorption mode using TPPI in t_1, the NOESY spectra were recorded with a mixing time of 0.5 s, two-dimensional spectra were collected as a 410–512 (t_1) real and 1024 (t_2) complex point time domain matrix with a spectral width of 8500 Hz in both dimensions; and (d) 1D NOE difference spectra were obtained on a Bruker AMX 400 using standard steady-state difference experiments;

the irradiation time was 1.5–2 s with sufficient power 59–63 dB, the resulting FIDs were Fourier transformed using an exponential multiplication with 1 Hz line broadening and subtracted. Chemical shifts (δ) are reported relative to tetramethylsilane, J values in Hz. Electronic absorption spectra were recorded on a JASCO 7800 in chloroform, extinction coefficients (ε) being given in 1 mol^{-1} cm^{-1}. IR spectra were recorded on a Perkin-Elmer FTIR 1720x with an ATR attachment, or as a KBr disc (Nicolet Magna 750). Mass spectra were measured on a MSBKh instrument (SELMI, Sumy, Ukraine); ionisation was caused by ^{252}Cf fission products, and a time-of-flight monitoring ion analyser was employed. FAB mass spectra were measured on a VG Autospec using caesium ion bombardment at 25 kV, a 3-nitrobenzyl alcohol matrix, and poly(ethylene glycol) as reference. HPLC was performed on Hypersil C18 silica gel. Preparative thin layer chromatography was carried out on Merck Kieselgel 60H. Analytical TLC was carried out on Merck HPTLC glass plates with concentration zone (silica gel 60 F_{254}). Melting points were determined on a Boetius hot-stage apparatus and are not corrected.

Bacteriopurpurin **1**, purpurin 18 **3a** and 3-acetyl-3-devinylpurpurin 18 **3b** were prepared as described.[28] For nomenclature purposes, IUPAC-IUB rules[29] are based on the trivial names bacteriopurpurin **1** and purpurin 18 **3a**.

3-(1-Hydroxyethyl)-3-deacetyl-15^1,15^1-dihydro-15^1-deoxobacteriopurpurin methyl ester 2

Bacteriopurpurin **1** (24 mg) was dissolved in pyridine (2 ml), treated with a suspension of $NaBH_4$ (25 mg) in propan-2-ol (30 ml), and the mixture was stirred for 3.5 h in the dark, before acetone (2 ml) was added, and the mixture was stirred for a further 30 min. Propan-2-ol–HCl (10 M) (10:1 v/v, 1 ml) was added, the reaction mixture was stirred for 10 min, diluted with chloroform (50 ml), washed with acidified water (2 × 300 ml with 0.5 ml conc. HCl added) and then with distilled water (300 ml). The organic layers were dried over anhydrous sodium sulfate, treated with diazomethane in ether, and evaporated to dryness on a rotary evaporator. The products were separated by HPLC in acetonitrile to give 9.5 mg (40%) of the title compound **2**; mp 190–194 °C; *m/z* (FAB) 584.2987 ($C_{34}H_{40}N_4O_5$ requires 584.2999); λ_{max}/nm ($\varepsilon/10^3$) 358 (72.00), 384 (49.00), 511 (17.30) and 724 (27.40); δ_H(600 MHz, method c) 8.70 (d, J 7, 5-H), 8.48 (s, 10-H), 8.22 (s, 20-H), 6.59 (d, J 14, 15^1-CH_2), 6.54 (d, J 14, 15^1-CH_2), 6.23 (q, J 7, 3^1-CH), 4.22 (m, 7-H), 4.18 (q, J 7, 18-H), 4.09 (dd, J 10 and 2, 17-H), 4.02 (m, 8-H), 3.62 (s, 17^5-CH_3), 3.56 (s, 12-CH_3), 3.27 (s, 2-CH_3), 2.52 (m, 17^2-CH_2), 2.32 (m, 8^1-CH_2 and 17^1-CH_2), 2.21 (m, 17^2-CH_2), 2.06 (d, J 7, 3^2-CH_3), 2.04 (m, 8^1-CH_2), 1.93 (m, 17^1-CH_2), 1.79 (dd, J 8 and 2, 7-CH_3), 1.64 (d, J 7, 18-CH_3), 1.11 (t, J 7, 8^2-CH_3), −0.16 (br s, NH) and −0.77 (br s, NH); ν_{max}(ATR)/cm^{-1} 3379, 1701 (bs) overlapping with 1686 (s), 1618 (s), 1586, 1368, 1201, 1130, 1061, 1010, 971, 896, 872, 803, 778, 675.

15^1,15^1-Dihydro-15^1-deoxopurpurin 18 methyl ester 4a

(a) Purpurin 18 **3a** (32 mg) was dissolved in pyridine (3 ml) and treated with a suspension of $NaBH_4$ (74 mg) in propan-2-ol (35 ml). The mixture was stirred for 2 h in the dark before acetone (2 ml) was added, and then stirred for a further 20 min. Conc. HCl–propan-2-ol (1:10 v/v, 2 ml) was added. The reaction mixture was diluted with chloroform (50 ml), washed with water (4 × 100 ml), the organic layers were dried over anhydrous sodium sulfate, treated with ethereal diazomethane and evaporated to dryness on a rotary evaporator. The products were separated by HPLC in an acetonitrile–water (10:1) eluting system. The first fraction contained 15^1,15^1-dihydro-15^1-deoxopurpurin 18 methyl ester **4a**; yield 11.4 mg (36%); mp 172–175 °C (CH_3CN) (lit. 145–147,[13] 177[14] and 184 °C[15]); *m/z* (FAB): 565.2802 ($C_{34}H_{36}N_4O_4$ + H requires 565.2815); λ_{max}/nm ($\varepsilon/10^3$) 404 (66.5), 500 (5.65), 531 (3.92), 610 (2.39) and 666 (21.95); δ_H(600 MHz, method c) 9.70 (s, 10-H), 9.53 (s, 5-H), 8.69 (s, 20-H), 8.02 (dd, J 18 and 11, 3^1-CH), 6.82 (s, 15^1-CH_2), 6.34 (d, J 18, 3^2-CH_2), 6.19 (d, J 11, 3^2-CH_2), 4.48 (q, J 7, 18-H), 4.36 (dd, J 10 and 2, 17-H), 3.87 (s, 12-CH_3), 3.75 (q, J 8, 8^1-CH_2), 3.62 (s, 17^5-CH_3), 3.45 (s, 2-CH_3), 3.28 (s, 7-CH_3), 2.61 (m, 17^2-CH_2), 2.25 (m, 17^2-CH_2), 2.46 (m, 17^1-CH_2), 2.01 (m, 17^1-CH_2), 1.75 (d, J 7, 18-CH_3), 1.72 (t, J 8, 8^2-CH_3), −1.06 (vbr, NH) and −1.70 (vbr, NH); ν_{max}(ATR)/cm^{-1} 3350, 1714 (bs), 1610, 1161 (s), 1030 (s), 978 (s), 896 (s), 673 (s).

The second fraction contained 13^1,13^1-dihydro-13^1-deoxopurpurin 18 methyl ester **5a**; yield 1.9 mg (6.2%); *m/z* (^{252}Cf) 565.3 (100%, M^+); λ_{max}/nm (relative intensities) 397, 500, 552 and 674 (1:0.08:0.05:0.32).

(b) To chlorin 5 (*ca.* 1 mg)[16] in anhydrous pyridine (0.5 ml) under nitrogen was added a suspension of $NaBH_4$ (5 mg) in anhydrous propan-2-ol. The mixture was stirred in the dark at room temperature for 1.5 h. Acetone (1 ml) was added, and stirring was continued for 20 min. Conc. HCl–propan-2-ol (1:10 v/v, 1 ml) was added followed by chloroform (10 ml). The organic layer was washed with aqueous HCl (2 M, 2 × 10 ml), water (2 × 10 ml) and aqueous $NaHCO_3$ (10 ml), dried (Na_2SO_4), concentrated, and treated with ethereal diazomethane briefly. Removal of the solvent gave a green solid which was indistinguishable from the above sample of the lactone **4a** on mixed TLC (R_f 0.59, $CHCl_3$–MeOH 98:2) and VIS spectroscopy [λ_{max}($CHCl_3$)/nm (ε ratios) 404 (2.98), 501 (0.33), 531 (0.18), 609 (0.14), 664 (1.00)].

3-(1-Hydroxyethyl)-3-devinyl-15^1,15^1-dihydro-15^1-deoxopurpurin 18 methyl ester 4c

3-Acetyl-3-devinylpurpurin 18 **3b** (30 mg) was dissolved in pyridine (2 ml), treated with a suspension of $NaBH_4$ (35 mg) in propan-2-ol (35 ml), and the mixture was stirred for 2 h in the dark before acetone (2 ml) was added, and then stirred for a further 20 min. 3% HCl (10 M) in propan-2-ol (2 ml) was added, the reaction mixture was diluted with chloroform (50 ml), washed with water (3 × 200 ml), the organic layers were dried over anhydrous sodium sulfate, treated with ethereal diazomethane, and evaporated to dryness on a rotary evaporator. The product was separated by HPLC in an acetonitrile–water (10:1) eluting system to give the title compound **4c**; yield 10.1 mg (33%); mp >350 °C; *m/z* (^{252}Cf) 582.4 (100%, M^+); λ_{max}/nm (relative intensities) 401 (Soret), 497, 526 and 659 (1:0.08:0.06:0.26); δ_H(400 MHz, method b) 9.74 (d, J 3, 5-H), 9.62 (s, 10-H), 8.62 (s, 20-H), 6.76 (d, J 18, 15^1-CH_2), 6.73 (d, J 18, 15-CH_2), 6.37 (q, J 6, 3^1-CH), 4.43 (q, J 8, 18-H), 4.29 (dd, J 9 and 2, 17-H), 3.81 (s, 12-CH_3), 3.70 (q, J 7, 8^1-CH_2), 3.61 (s, 17^5-CH_3), 3.39 (s, 2-CH_3), 3.24 (s, 7-CH_3), 2.35 (m, 17^1-CH_2), 2.56 (m, 17^2-CH_2), 2.18 (m, 17^2-CH_2), 2.10 (d, J 6, 3^2-CH_3), 1.90 (m, 17^1-CH_2), 1.70 (d, J 8, 18-CH_3) and 1.68 (t, J 7, 8^2-CH_3).

(17*S*,18*R*)-18-Hydroxypurpurin 18 δ-lactone 8a

Purpurin 18 **3a** (60 mg) was dissolved in chloroform (10 ml), treated with a suspension of DDQ (48 mg) in chloroform (10 ml), and the reaction mixture was stirred for 4 h in the dark. The mixture was diluted with chloroform (30 ml), washed with water (3 × 200 ml), and the chloroform layer was dried over anhydrous sodium sulfate and evaporated to dryness. The title compound **8a** was separated by preparative TLC on silica with chloroform–acetone (20:1) to give 25.4 mg (42.5%) of (**8a**); mp >350 °C; *m/z* (FAB) 563.2297 ($C_{33}H_{30}N_4O_5$ + H requires 563.2294); λ_{max}/nm ($\varepsilon/10^3$) 411 (82.50), 479 (3.90), 509 (5.00), 547 (19.80), 642 (6.50) and 697 (41.25); δ_H(400 MHz, method d) 9.64 (s, 10-H), 9.53 (s, 5-H), 8.82 (s, 20-H), 7.91 (dd, J 18 and 12, 3^1-CH), 6.32 (dd, J 18 and 0.8, 3^2-CH_2), 6.22 (dd, J 12 and 0.8, 3^2-CH_2), 5.59 (dd, J 4 and 4, 17-H), 3.75 (s, 12-CH_3), 3.64 (q, J 8, 8^1-CH_2), 3.39 (s, 2-CH_3), 3.19 (s, 7-CH_3), 2.99 (m, 17^1-CH_2), 2.48 (m, 17^2-CH_2), 2.30 (m, 17^1-CH_2), 2.17 (s, 18-CH_3),

1.66 (t, J 8, 8^2-CH_3), 1.63 (m, 17^2-CH_2), −0.15 (br s, NH) and −0.47 (br s, NH); ν_{max}(KBr)/cm^{-1} 3350, 1753 (s), 1726 (s), 1604, 1527 (s), 1397, 1308, 1134, 1105 (s), 1059, 1049, 995 (s).

(17*S*,18*R*)-3-Acetyl-3-devinyl-18-hydroxypurpurin 18 δ-lactone 8b

3-Acetyl-3-devinylpurpurin 18 **3b** (40 mg) was dissolved in chloroform (10 ml), treated with a suspension of DDQ (40 mg) in chloroform (10 ml), and the reaction mixture was stirred for 1.5 h in the dark. The mixture was diluted with chloroform (30 ml), washed with water (2 × 200 ml), and the chloroform layer was dried over anhydrous sodium sulfate and evaporated to dryness. Preparative TLC on silica with chloroform–acetone (20:1) gave 16.4 mg (41%) of the title compound **8b**; mp 224–226 °C; m/z (^{252}Cf) 579.7 (100%, M + 1); λ_{max}/nm (ε/10^3) 412 (85.00), 483 (4.35), 512 (5.00), 551 (19.55), 661 (6.65) and 719 (46.75); δ_H(200 MHz, method a) 10.18 (s, 5-H), 9.73 (s, 10-H), 9.00 (s, 20-H), 5.62 (dd, J 8 and 5, 17-H), 3.70 (s, 12-CH_3), 3.63 (s, 2-CH_3), 3.59 (q, J 8, 8^1-CH_2), 3.20 (s, 3^2-CH_3), 3.17 (s, 7-CH_3), 2.98 (m, 17^1-CH_2), 2.49 (m, 17^2-CH_2), 2.23 (m, 17^1, 17^2-CH_2), 2.18 (s, 18-CH_3), 1.69 (t, J 8, 8^2-CH_3), −0.45 (br s, NH), −0.57 (br s, NH); ν_{max}(KBr)/cm^{-1} 3350 (s), 1754 (s), 1733 (s), 1668, 1609, 1546, 1524, 1377, 1201, 1131, 1114, 1030.

(17*S*,18*R*)-18-Hydroxypurpurin 18 methyl ester 9a

The hydroxypurpurin 18 δ-lactone **8a** (20 mg) was dissolved in TFA (1 ml), methanol was added (10 ml), and the mixture was stirred for 2 h in the dark. The mixture was diluted with chloroform (50 ml), washed with water (4 × 400 ml), and the chloroform layer was dried over anhydrous sodium sulfate and evaporated to dryness. Preparative TLC on silica in chloroform–ethanol (10:1) gave 8.0 mg (39%) of the title compound **9a**; mp >350 °C; m/z (FAB) 594.2509 ($C_{34}H_{34}N_4O_6$ requires 594.2478); λ_{max}/nm (ε/10^3) 412 (84.00), 480 (3.95), 511 (5.10), 549 (18.50), 647 (6.45) and 702 (36.10); δ_H(400 MHz, method d) 9.57 (s, 10-H), 9.34 (s, 5-H), 8.80 (s, 20-H), 7.80 (dd, J 18 and 12, 3^1-CH), 6.24 (dd, J 18 and 1, 3^2-CH_2), 6.16 (dd, J 12 and 1, 3^2-CH_2), 5.30 (dd, J 6 and 1, 17-H), 4.85 (s, 18-OH), 3.77 (s, 12-CH_3), 3.63 (q, J 8, 8^1-CH_2), 3.33 (s, 17^5-CH_3), 3.28 (s, 2-CH_3), 3.16 (s, 7-CH_3), 2.61 (m, 17^1-CH_2), 2.29 (m, 17^2-CH_2), 1.83 (s, 18-CH_3), 1.66 (t, J 8, 8^2-CH_3), 0.08 (br s, NH) and −0.28 (br s, NH); ν_{max}(KBr)/cm^{-1} 3350 (s), 1743 (s), 1717 (s), 1606 (s), 1527 (s), 1305, 1173, 1131, 1118, 1106, 1064, 1049, 994.

(17*S*,18*R*)-3-Acetyl-3-devinyl-18-hydroxypurpurin 18 methyl ester 9b

3-Acetyl-3-devinyl-18-hydroxypurpurin 18 δ-lactone **8b** (20 mg) was dissolved in TFA (1 ml), methanol was added (15 ml), and the mixture was stirred for 4 h in the dark. The mixture was diluted with chloroform (50 ml), washed with water (4 × 400 ml), and the chloroform layer was dried over anhydrous sodium sulfate and evaporated to dryness. Preparative TLC on silica in chloroform–acetone (20:1) gave 8.5 mg (41%) of the title compound **9b**; mp >350 °C; m/z (^{252}Cf) 610.6 (100%, M$^+$); λ_{max}/nm (ε/10^3) 414 (89.00), 484 (2.40), 514 (3.38), 554 (18.70), 684 (6.05) and 725 (44.50); δ_H(200 MHz, method a) 10.00 (s, 5-H), 9.70 (s, 10-H), 9.00 (s, 20-H), 5.38 (dd, J 8 and 1, 17-H), 4.80 (s, 18-OH), 3.83 (s, 12-CH_3), 3.66 (q, J 8, 8^1-CH_2), 3.57 (s, 17^5-CH_3), 3.30 (s, 2-CH_3), 3.20 (s, 3^2-CH_3), 3.19 (s, 7-CH_3), 2.60 (m, 17^1-CH_2), 2.26 (m, 17^2-CH_2), 1.85 (s, 18-CH_3), 1.66 (t, J 8,8^2-CH_3), −0.15 (br s, NH) and −0.32 (br s, NH); ν_{max}(KBr)/cm^{-1} 3350, 1750 (bs), 1667, 1607, 1543, 1519, 1377, 1169, 1134, 1114, 1051, 1021 (s).

17,18-Didehydropurpurin 18 methyl ester (purpuroporphyrin 18 methyl ester) 11a

(a) Purpurin 18 methyl ester **10a** (40 mg) was dissolved in chloroform (10 ml), treated with a suspension of DDQ (30 mg) in chloroform (10 ml), and the reaction mixture was stirred for 2 h in the dark. The mixture was diluted with chloroform (30 ml), washed with water (3 × 200 ml), and the chloroform layer was dried over anhydrous sodium sulfate and evaporated to dryness. Preparative TLC on silica in chloroform–acetone (20:1) gave 18.2 mg (45.5%) of **11a**; mp >350 °C; m/z (FAB) 576.2371 ($C_{34}H_{32}N_4O_5$ requires 576.2373); λ_{max}/nm (relative intensities) 429 (Soret), 525, 565, 610 and 661 (1:0.02:0.04:0.10:0.12); δ_H(200 MHz, method a) 9.43 and 9.30 (2 s, 5-H, 10-H), 8.95 (s, 20-H), 7.93 (dd, J 18 and 11, 3^1-CH), 6.24 (dd, J 18 and 2, 3^2-CH_2), 6.17 (dd, J 11 and 2, 3^2-CH_2), 3.88 (t, J 8, 17^1-CH_2), 3.78 (q, J 8, 8^1-CH_2), 3.52 and 3.43 (2 s, 12-CH_3, 17^5-CH_3), 3.33 (s, 2-CH_3), 3.28 (s, 18-CH_3), 3.20 (s, 7-CH_3), 3.10 (t, J 8, 17^2-CH_2), 1.62 (t, J 8, 8^2-CH_3), −5.15 (vbr, NH) and −5.78 (vbr, NH); ν_{max}(KBr)/cm^{-1} 3350 (s), 1751 (s), 1726 (s), 1631, 1596, 1098, 1058.

(b) The 18-hydroxypurpurin 18 δ-lactone **8a** (30 mg) was dissolved in TFA (1 ml), methanol was added (10 ml), and the mixture was stirred for 24 h in the dark. The mixture was diluted with chloroform (50 ml), washed with water (4 × 400 ml), and the chloroform layer was dried over anhydrous sodium sulfate and evaporated to dryness. Preparative TLC on silica in chloroform–ethanol (10:1) gave 3.6 mg (12%) of the product **11a**. The TLC, MS and ^{1}H NMR data were identical with those of **11a** obtained as described in the previous experiment.

(c) 18-Hydroxypurpurin 18 methyl ester **9a** (20 mg) was dissolved in TFA (1 ml) and the mixture was stirred for 12 h. Then the mixture was diluted with chloroform (50 ml), washed with water (3 × 150 ml), and the chloroform layer was dried over anhydrous sodium sulfate and evaporated to dryness. Preparative TLC on silica in chloroform–acetone (100:1) gave 4 mg (21%) of the product **11a**, the TLC and MS data of which were identical with those of the above samples of this substance.

3-Acetyl-3-devinyl-17,18-didehydropurpurin 18 methyl ester (3-acetyl-3-devinylpurpuroporphyrin 18 methyl ester) 11b

(a) 3-Acetyl-3-devinylpurpurin 18 methyl ester **10b** (40 mg) was dissolved in chloroform (10 ml), treated with a suspension of DDQ (40 mg) in chloroform (10 ml), and the reaction mixture was stirred for 2 h in the dark. The mixture was diluted with chloroform (40 ml), washed with water (3 × 200 ml), and the chloroform layer was dried over anhydrous sodium sulfate and evaporated to dryness. Preparative TLC on silica in chloroform–acetone (20:1) gave 19.6 mg (49%) of **11b**; mp >350 °C; m/z (FAB) 593.2387 ($C_{34}H_{32}N_4O_6$ + H requires 593.2400); λ_{max}/nm (ε/10^3) 430 (126), 530 (4.4), 568 (6.3), 616 (15.2) and 662 (16.4); δ_H(200 MHz, method a) 10.35 (s, 5-H), 9.36 (s, 10-H), 8.85 (s, 20-H), 3.89 (q, J 8, 8^1-CH_2), 3.88 (t, J 8, 17^1-CH_2), 3.72 (s, 12-CH_3), 3.60 (s, 17^5-CH_3), 3.53 (s, 2-CH_3), 3.53 (s, 18-CH_3), 3.34 (s, 3^2-CH_3), 3.28 (s, 7-CH_3), 3.05 (t, J 8, 17^2-CH_2), 1.59 (t, J 8, 8^2-CH_3), −5.45 (vbr, NH), −6.18 (vbr, NH); ν_{max}(KBr)/cm^{-1} 3350, 1755 (s), 1728 (s), 1656, 1597, 1376, 1361, 1353, 1385, 1271, 1196, 1171, 1152, 1132, 1100 (s), 1050 (s), 979, 782.

(b) 3-Acetyl-3-devinyl-18-hydroxypurpurin 18 δ-lactone **8b** (25 mg) was dissolved in TFA (1 ml), methanol was added (15 ml), and the mixture was stirred for 24 h in the dark. The mixture was diluted with chloroform (50 ml), washed with water (4 × 400 ml), and the chloroform layer was dried over anhydrous sodium sulfate and evaporated to dryness. Preparative TLC on silica in chloroform–acetone (20:1) gave 4.0 mg (16%) of the product **11b**, the TLC, MS and ^{1}H NMR data of which were identical to those of **11b** obtained as described in the previous experiment.

17,18-Didehydrochlorin p_6 trimethyl ester (chloroporphyrin p_6 trimethyl ester) 12a

Purpuroporphyrin 18 methyl ester **11a** (18 mg) was dissolved in a solution of NaOH (5 mg) in methanol (15 ml), and the reac-

tion mixture was stirred for 15 min in the dark. The mixture was taken to dryness, dissolved in water (30 ml), and treated with 10% aqueous HCl to pH 6. The precipitate was filtered off, dissolved in methanol (10 ml), and treated with diazomethane in ether. The reaction mixture was evaporated to dryness, and the title product was separated by preparative TLC on silica in chloroform–acetone (20:1) to give 11 mg (61%) of **12a**; mp >350 °C; *m/z* (FAB) 623.2926 ($C_{36}H_{30}N_4O_6$ + H requires 623.2870); λ_{max}/nm (relative intensities) 408 (Soret), 512, 550, 577 and 632 (1:0.06:0.07:0.05:0.02); δ_H(200 MHz, method a) 10.02, 10.00 and 9.92 (3 s, 5-H, 10-H and 20-H), 8.08 (dd, *J* 18 and 11, 3^1-CH), 6.23 (dd, *J* 18 and 2, 3^2-CH_2), 6.09 (dd, *J* 11 and 2, 3^2-CH_2), 4.44 and 4.32 (2 s, 13^3-CH_3, 15^3-CH_3), 4.06 (t, *J* 9, 17^1-CH_2), 4.00 (q, *J* 8, 8^1-CH_2), 3.78, 3.67, 3.61, 3.54, 3.52 (5 s, 2-CH_3, 7-CH_3, 12-CH_3, 17^5-CH_3, 18-CH_3), 3.09 (t, *J* 9, 17^2-CH_2), 1.80 (t, *J* 8, 8^2-CH_3) and −3.76 (vbr, 2 NH).

3-Acetyl-3-devinyl-17,18-didehydrochlorin p_6 trimethyl ester (3-acetyl-3-devinylchloroporphyrin p_6 trimethyl ester) 12b

(a) 3-Acetyl-3-devinylpurpuroporphyrin 18 methyl ester **11b** (24 mg) was dissolved in a solution of NaOH (15 mg) in methanol (15 ml), and stirred for 20 min in the dark. The mixture was taken to dryness, dissolved in water (20 ml), and treated with 10% aqueous HCl to pH 6. The precipitate was filtered off, dissolved in methanol (10 ml), and treated with diazomethane in ether. The reaction mixture was evaporated to dryness. Preparative TLC on silica in chloroform–acetone (20:1) gave 15.3 mg (64%) of **12b**; mp 256–260 °C; *m/z* (^{252}Cf) 638.9 (100%, M^+); λ_{max}/nm (relative intensities) 413 (Soret), 517, 559, 582 and 637 (1:0.05:0.07:0.05:0.015); δ_H(200 MHz, method a) 10.27 (s, 5-H), 9.85 (s, 10-H), 9.67 (s, 20-H), 4.47 and 4.32 (2 s, 13^3-CH_3, 15^3-CH_3), 4.06 (t, *J* 8, 17^1-CH_2), 3.97 (q, *J* 8, 8^1-CH_2), 3.80, 3.63, 3.59, 3.49, 3.47 and 3.17 (6 s, 2-CH_3 3^2-CH_3, 7-CH_3, 12-CH_3, 17^5-CH_3, 18-CH_3), 3.04 (t, *J* 8, 17^2-CH_2), 1.76 (t, *J* 8, 8^2-CH_3), −4.38 (br s, NH) and −4.78 (br s, NH).

(b) 3-Acetyl-3-devinyl-18-hydroxypurpurin 18 δ-lactone **8b** (20 mg) was dissolved in a solution of NaOH (10 mg) in methanol (15 ml), and stirred for 24 h in the dark. The mixture was taken to dryness, dissolved in water (20 ml), and treated with 10% aqueous HCl to pH 6. The precipitate was filtered off, dissolved in methanol (10 ml), and treated with diazomethane in ether. The reaction mixture was evaporated to dryness, and the title product was separated by preparative TLC on silica in chloroform–acetone (20:1) to give 2.4 mg (12%) of **12b**, the TLC, MS and ^{1}H NMR data of which were identical to those of **12b** obtained as described above.

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