

PYRIDINONE COMPOUNDS FOR USE IN PHOTODYNAMIC THERAPY

Field of the invention

- 5 The present invention relates to a novel compound and its preparation and use, and to compositions comprising the compound.

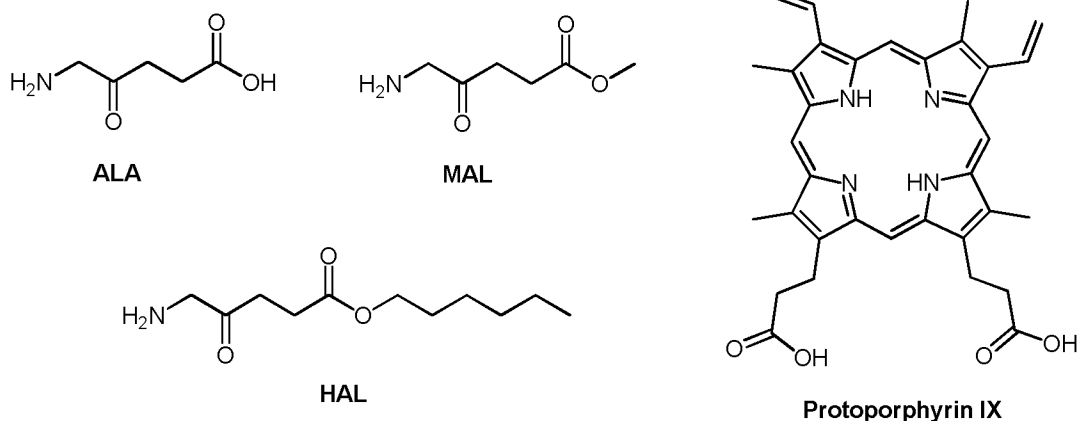
Background to the invention

- Photodynamic therapy (PDT) is a therapy employed routinely in the treatment of superficial dermatological malignancies and is under investigation for a range of additional tumour types.
- 10 Most applications of PDT involve the use of an active compound, known as a photosensitizer, and a light source, the wavelength of which can be chosen to be appropriate for exciting the photosensitizer to produce reactive oxygen species. This leads to the destruction of any tissues which have either selectively taken up the photosensitizer or have been locally exposed to light.
- 15 For example, a PDT treatment of human skin cancer may involve the following steps. Firstly, a photosensitizer precursor is administered to the patient. The photosensitizer precursor is taken up by the cells and converted to a photosensitizer. The area to be treated is then exposed to light of the appropriate wavelength. The photosensitizer absorbs light and reacts with nearby tissue oxygen, resulting in reactive oxygen species. These reactive oxygen
- 20 species react with biomolecules, fatally damaging some of the cells in the treatment area.

- PDT has particularly found a niche in the treatment of dermatological tumours where light can be readily applied to the surface of the skin; clinically substantial subsets of skin tumours are difficult to treat by conventional therapies (because of size, site or multiple lesions presentation). In the treatment of skin conditions, the photosensitizer or photosensitizer
- 25 precursor can be applied topically, and locally excited by a light source. In the local treatment of internal cancer cells, on the other hand, photosensitizers or photosensitizer precursors can

for example be administered intravenously and light can be delivered to the target area using endoscopes and fibre optic catheters. Compared to normal healthy tissues, most types of cancer cells are especially active in both the uptake and accumulation of photosensitizers, which makes cancer cells especially vulnerable to PDT, since having more photosensitizer present in a cell leads to more damage to that cell during PDT.

Photosensitizer precursors currently employed in dermatological PDT include aminolevulinic acid (ALA), methyl aminolevulinate (MAL) and hexyl aminolevulinate (HAL). If ALA, MAL or HAL is used as a photosensitizer precursor, it is converted by the cells to the photosensitizer protoporphyrin IX (PpIX).



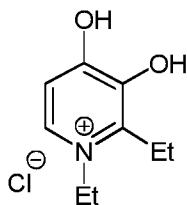
Porphyrins have long been considered as suitable agents for tumour photodiagnosis and tumour PDT because cancer cells exhibit a significantly greater uptake and affinity for porphyrins compared to normal quiescent tissues; cancer cells therefore naturally accumulate porphyrins.

An additional feature of the photosensitizer protoporphyrin IX (PpIX) is its ability to fluoresce, which in combination with cancer cells' natural accumulation of porphyrins allows for photodiagnosis (PD) of tumours. PD has been used by surgeons for enabling greater precision in the removal of tumours, such as for example brain tumours.

PpIX is naturally present in all nucleated mammalian cells at low concentrations; it is an intermediate in the biosynthesis of haem. In the haem biosynthesis, ALA is converted to PpIX

(via a number of intermediate steps), after which PpIX is converted to haem by the insertion of a Fe^{2+} ion into PpIX by the enzyme ferrochelatase.

- In order for PDT to be effective, it is necessary to increase the amount of PpIX which is present in a cell. One way of doing this is to add more ALA, MAL or HAL to a cell, which will be converted to PpIX. However, the haem biosynthesis pathway has a maximum limit over which additional precursor administration does not produce any additional benefit. Furthermore, excessive ALA oral administration has been demonstrated to induce liver toxicity in humans. Usually, the presence of free haem acts as a negative feedback mechanism inhibiting ALA synthesis. However, the exogenous administration of large amounts of ALA or MAL bypasses this negative feedback signal and results in a temporary accumulation of PpIX within the cells, since the insertion of Fe^{2+} into PpIX to form haem is relatively slow. Furthermore, PpIX may accumulate in the cell even more by slowing down the step of converting PpIX to haem by insertion of Fe^{2+} , which may be achieved by limiting the iron supply in a cell. Bech, O. *et al.*, J Photochem Photobiol B, 1997, 41, 136-144; Curnow, A. *et al.*, BJC, 1998, 78, 1278-1282; Pye, A. *et al.*, Photochem Photobiol, 2007, 83(3), 766-73; and Blake, E. *et al.*, Photochem Photobiol, 2010, 86(5), 1154-60 describe how the use of the iron chelator CP94, shown below, in combination with ALA can increase accumulation of PpIX.



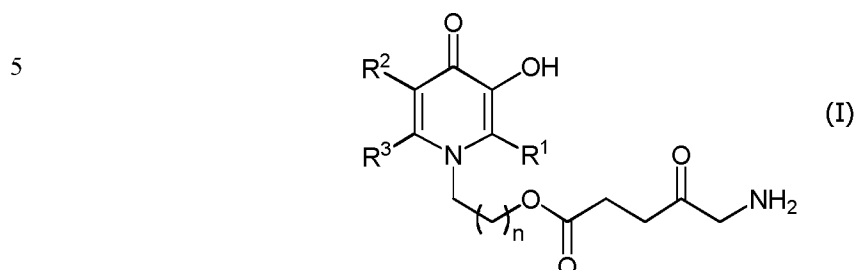
CP94

- A need however remains for new photosensitizer precursors which have an improved activity profile in photodynamic therapy, especially since currently photodynamic therapy is not effective for all tumour types; clearance rates for thicker nodular basal cell carcinoma (BCC), for example, remain lower than for superficial BCC.

- It is an aim of the invention to provide a new compound which can be used as a photosensitizer precursor, and which can show an improved activity profile in photodynamic therapy.

Statements of the invention

According to a first aspect of the invention there is provided a compound which is a compound of formula (I) or any salt thereof:

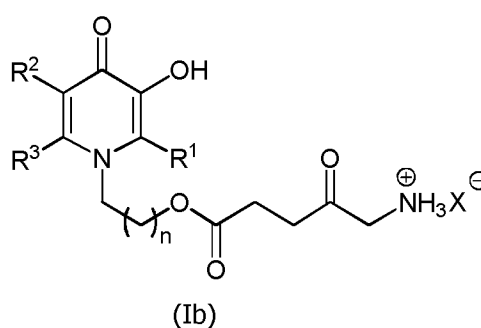
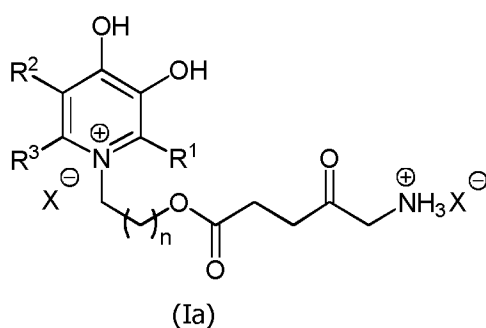


10 wherein

- R^1 is a C_1 - C_6 alkyl group,
- R^2 is H or a C_1 - C_6 alkyl group,
- R^3 is H or a C_1 - C_6 alkyl group, and
- n is an integer from 0 to 5.

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In an embodiment, the compound according to the first aspect of the invention is a compound of formula (I) as defined above, a salt of formula (Ia) or a salt of formula (Ib):



20 wherein

- R^1 , R^2 , R^3 and n are as defined above; and
- each X^- is independently selected from monovalent counterions.

25 In an embodiment, the compound according to the first aspect of the invention is a compound of formula (I) or a salt of formula (Ia) as defined above. In an embodiment, the compound according to the first aspect of the invention is a compound of formula (I) as defined above.

In an embodiment, the compound according to the first aspect of the invention is a salt of formula (Ia) as defined above.

The monovalent counterion X^- may be the conjugate base of any common acid. X^- may, for example, be a halide, hydrogen sulphate, nitrate, or a carboxylate such as acetate or formate.

In an embodiment, X^- is a halide, such as, for example, F^- , Cl^- , Br^- or I^- . In an embodiment, X^- is Cl^- .

10 An alkyl group may be a straight or branched chain alkyl group.

In the compound according to the first aspect of the invention, R^1 is a C_1 - C_6 alkyl group, which includes, for example, methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl, *t*-butyl, *n*-pentyl, *i*-pentyl, *t*-pentyl and hexyl. In an embodiment, R^1 is a C_1 - C_5 alkyl group, which includes, for example, methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl, *t*-butyl, *n*-pentyl, *i*-pentyl, and *t*-pentyl. In an embodiment, R^1 is a C_1 - C_4 alkyl group, which includes, for example, methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl and *t*-butyl. In an embodiment, R^1 is a C_1 - C_3 alkyl group, which includes, for example, methyl, ethyl, *n*-propyl and *i*-propyl. In an embodiment, R^1 is a C_1 - C_2 alkyl group, i.e. methyl or ethyl. In an embodiment, R^1 is a C_2 alkyl group, i.e. ethyl.

20 In the compound according to the first aspect of the invention, R^2 is H or a C_1 - C_6 alkyl group, which includes, for example, methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl, *t*-butyl, *n*-pentyl, *i*-pentyl, *t*-pentyl and hexyl. In an embodiment, R^2 is H or a C_1 - C_5 alkyl group, which includes, for example, methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl, *t*-butyl, *n*-pentyl, *i*-pentyl, and *t*-pentyl. In an embodiment, R^2 is H or a C_1 - C_4 alkyl group, which includes, for example, methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl and *t*-butyl. In an embodiment, R^2 is H or a C_1 - C_3 alkyl group, which includes, for example, methyl, ethyl, *n*-propyl and *i*-propyl. In an embodiment, R^2 is H or a C_1 - C_2 alkyl group, i.e. methyl or ethyl. In an embodiment, R^2 is H.

30 In the compound according to the first aspect of the invention, R^3 is H or a C_1 - C_6 alkyl group, which includes, for example, methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl, *t*-butyl, *n*-pentyl, *i*-pentyl, *t*-pentyl and hexyl. In an embodiment, R^3 is H or a C_1 - C_5 alkyl group, which includes, for example, methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl, *t*-butyl, *n*-pentyl, *i*-pentyl, and *t*-pentyl. In an embodiment, R^3 is H or a C_1 - C_4 alkyl group, which includes, for example, methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl and *t*-butyl. In an embodiment, R^3 is H or a C_1 - C_3 alkyl group,

which includes, for example, methyl, ethyl, *n*-propyl and *i*-propyl. In an embodiment, R³ is H or a C₁-C₂ alkyl group, i.e. methyl or ethyl. In an embodiment, R³ is H.

In an embodiment, R² and R³ are H.

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In the compound according to the first aspect of the invention, n is an integer from 0 to 5. In an embodiment, n is from 0 to 4, or from 0 to 3, or from 0 to 2, or from 0 to 1, or from 1 to 5, or from 1 to 4, or from 1 to 3, or from 1 to 2. In an embodiment, n is 1.

- 10 In an embodiment, R¹ is methyl or ethyl; R² is H, methyl or ethyl; R³ is H, methyl or ethyl; and n is 1.

In an embodiment, R¹ is ethyl, R² and R³ are H, and n is 1. This compound and its salt forms are effectively a combination of ALA and the iron chelating compound CP94, which have been
15 linked via an ester linkage. Surprisingly, this linked compound has a better activity profile than a combination of ALA and CP94 as separate active agents.

This is highly surprising for a number of reasons. Firstly, delivering ALA and CP94 in a linked format (rather than separately) might be expected to alter the way the compounds enter the cell; bigger molecules tend to not enter cells as effectively as smaller molecules and may use
20 different transporters. In fact, it is thought that ALA and MAL may enter cells via different membrane transporters and hence this might also have been true for the compound of the invention in which ALA and CP94 are linked. This new entity, therefore, was not guaranteed to produce even the same level of results as ALA and CP94 as separate agents, let alone better ones.

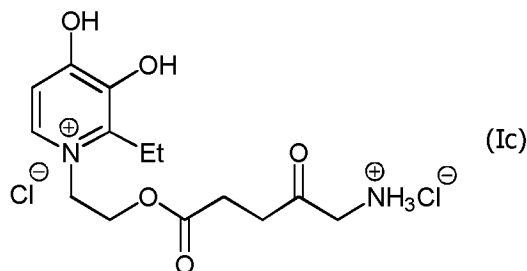
25 In addition to this, it was very difficult to predict how the linked format would affect the innate cellular biochemistry relied on to produce the natural photosensitiser PpIX. ALA is normally formed by ALA synthase in the mitochondrion before entering the portion of the haem biosynthesis pathway that occurs in the cytosol. The later step of insertion of iron into the PpIX porphyrin ring to form haem occurs in the mitochondrion. In order to influence this
30 pathway in such a way that PpIX accumulates, the iron chelator needs to be able to diminish mitochondrial levels of iron either directly or indirectly. However, the compound of the invention in which ALA and CP94 are linked first needs to be separated into the active agents by esterases present in the cytosol. The linked format might therefore be expected to alter

the cellular compartments (such as the cytosol and the mitochondrion) in which the separate compounds end up, which could also alter the regulation of the haem biosynthetic pathway. In addition, in theory it might seem better to deliver the CP94 before the ALA, in order to chelate the iron prior to producing the PpIX, whereas delivering the agents in a linked format means that the agents are delivered simultaneously. These factors contributed further to render the utility of the invented compound even more surprising.

Furthermore, iron chelator CP94 is bidentate and it therefore takes three CP94 molecules to bind one Fe^{2+} ion. In addition to this, in the haem biosynthesis pathway two molecules of ALA dimerize to form porphobilinogen after which four molecules of the latter are condensed, rearranged and cyclised to produce uroporphyrinogen III; this is then converted into protoporphyrin IX via coproporphyrinogen III. Therefore, eight molecules of ALA are needed to form one PpIX molecule, which binds to one Fe^{2+} ion to form one molecule of haem. The theoretical ratio of ALA : CP94 required per Fe^{2+} ion would, therefore, in simplistic biosynthetic terms, be 8 ALA : 3 CP94, i.e. over twice as much ALA as CP94. Despite this, the inventors have found that, highly surprisingly, equal quantities of ALA and CP94 in the specific linked format of the compound of the invention give an excellent activity profile. Without wishing to be bound by theory, in retrospect it may be the case that, in order to make haem formation from PpIX less likely to occur, more CP94 may be required than was theoretically predicted in order to drain the intracellular iron stores.

As set out above, there are a large number of different factors in the environment inside a living cell which influence the activity profile of any active agent added to it, making it very difficult to predict the success of the active agent. It was, therefore, highly surprising to find that equal quantities of ALA and CP94 in the specific linked format of the compound of the invention gave such an excellent activity profile.

In an embodiment, the compound according to the first aspect of the invention is a salt of formula (Ic):



As can be seen from Example 2B, the salt of formula (Ic) is able to produce a significant increase in PpIX accumulation relative to ALA, MAL, a combination of ALA and CP94 as separate active agents, and a combination of MAL and CP94 as separate active agents. Furthermore, as can be seen from Example 2C, the salt of formula (Ic) was also found to be significantly better at reducing cell viability following PDT, especially at low concentrations.

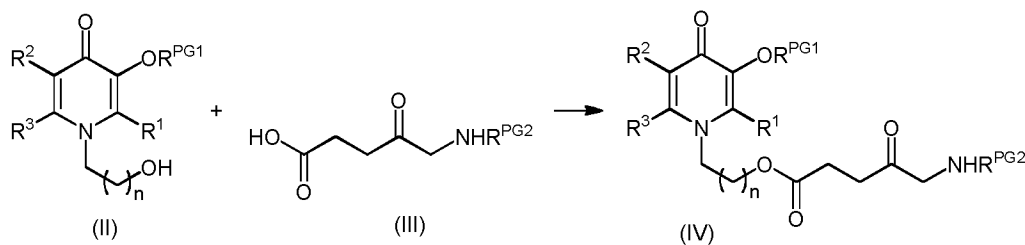
The clinical employment of the salt of formula (Ic) could, therefore, lead to a substantial benefit to patients undergoing dermatological PDT and other PDT applications.

According to a second aspect of the invention there is provided a pharmaceutical composition comprising a compound according to the first aspect of the invention and a pharmaceutically acceptable carrier. Throughout this specification, the term "pharmaceutical" includes veterinary. In an embodiment, the composition is a topical skin treatment formulation.

According to a third aspect of the invention there is provided a process for making a compound according to the first aspect of the invention, the method comprising the step of:

(a) reacting a compound of formula (II) with a compound of formula (III) via an esterification reaction to form a compound of formula (IV);

in accordance with the following reaction scheme:



wherein R^1 , R^2 , R^3 and n are as defined for the first aspect; and R^{PG1} and R^{PG2} are protecting groups.

The term "protecting group" means a group capable of protecting an oxygen atom or a nitrogen atom, which protecting group may, subsequent to the reaction for which protection is employed, be removed without disturbing the remainder of the molecule. Protecting groups are well known and listed in standard texts such as Kocienski P. J., *Protecting Groups*, 3rd ed., Georg Thieme Verlag, New York, 2005; and Greene T. W., Wuts P. G. M., *Protective Groups In Organic Synthesis*, 3rd ed., John Wiley & Sons, New York, 1998.

In an embodiment, R^{PG1} is a protecting group selected from benzyl, benzoyl, methoxymethyl (MOM), methoxyethoxymethyl ether (MEM), tetrahydropyranyl (THP), and silicon protecting groups such as, for example, trimethylsilyl (TMS), triethylsilyl (TES), triisopropylsilyl (TIPS), triphenylsilyl (TPS), t-butyldimethylsilyl (TBDMS), t-butyldiphenylsilyl (TBDPS),
 5 (dimethyl)hexylsilyl, and 2-(trimethylsilyl)ethoxymethyl (SEM).

R^{PG1} is an alcohol protecting group. Alcohol protecting groups are well-known to the skilled person and listed in standard texts such as those mentioned above.

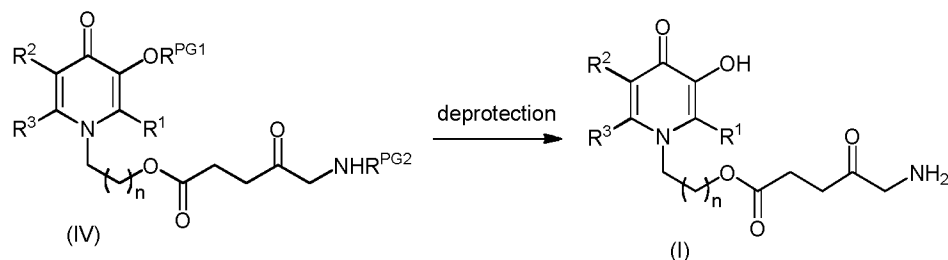
In an embodiment, R^{PG2} is a protecting group selected from benzoyl and urethane-type protecting groups such as carboxybenzyl (Cbz), *tert*-butoxycarbonyl (Boc),
 10 4-methoxybenzyloxycarbonyl, 4-nitrobenzyloxycarbonyl and 9-fluorenylmethyloxycarbonyl (Fmoc).

R^{PG2} is a primary amine protecting group. Primary amine protecting groups are well-known to the skilled person and listed in standard texts such as those mentioned above.

In an embodiment, the process according to the third aspect further comprises the step of:

15 (b1) deprotecting the compound of formula (IV) to give a compound of formula (I);

in accordance with the following reaction scheme:

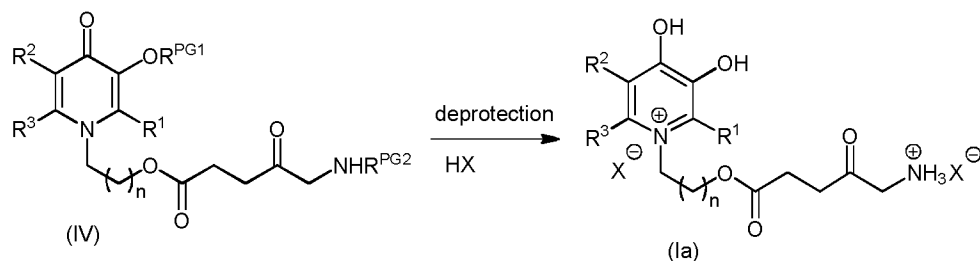


Protection and deprotection can be carried out in the usual ways known to the skilled person;
 20 these are routine steps in chemical synthesis.

In an embodiment, the process according to the third aspect further comprises the step of:

(b2) deprotecting the compound of formula (IV) in the presence of acid H^+X^- to give a salt of formula (Ia);

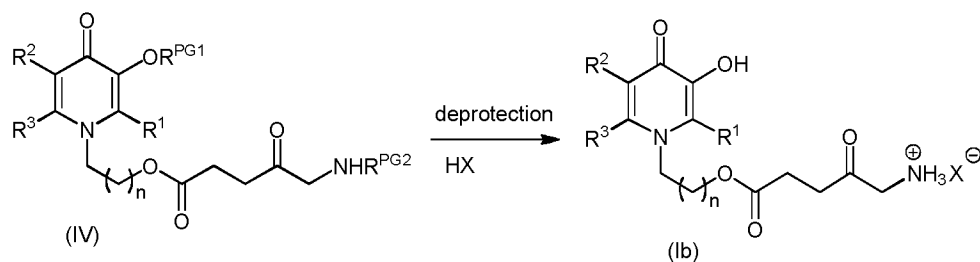
25 in accordance with the following reaction scheme:



In an embodiment, the process according to the third aspect further comprises the step of:

- (b3) deprotecting the compound of formula (IV) in the presence of acid H^+X^- to give a salt of formula (Ib);

in accordance with the following reaction scheme:



- 10 According to a fourth aspect of the invention there is provided a compound according to the first aspect of the invention for use in therapy.

According to a fifth aspect of the invention there is provided a compound according to the first aspect of the invention for use in photodynamic therapy.

- 15 In an embodiment, the compound for use according to the fifth aspect of the invention is for use in treating a condition, which is caused by and/or exacerbated by the abnormal proliferation of cells, by photodynamic therapy.

- 20 In an embodiment, the compound for use according to the fifth aspect of the invention is for use in treating cancer, by photodynamic therapy. In an embodiment, the compound is for use in treating skin cancer, by photodynamic therapy. In an embodiment, the compound is for use in treating internal cancer cells, by photodynamic therapy.

In an embodiment, the compound for use according to the fifth aspect of the invention is for use in treating scleroderma, lichen sclerosus, psoriasis or warts, by photodynamic therapy. In an embodiment, the compound for use according to the fifth aspect of the invention is for use in treating chronic wounds, by photodynamic therapy. Such chronic wounds may, for example, be leg ulcers in the elderly. In an embodiment, the compound for use according to the fifth aspect of the invention is for use in treating acne, by photodynamic therapy. In an embodiment, the compound for use according to the fifth aspect of the invention is for use in treating a microbial infection, by photodynamic therapy. Such a microbial infection may, for example, be caused by bacteria, fungi, viruses and/or yeasts. In an embodiment, the compound for use according to the fifth aspect of the invention is for use in treating a parasitic infestation, by photodynamic therapy. In an embodiment, the compound for use according to the fifth aspect of the invention is for use in treating rheumatoid arthritis, by photodynamic therapy. In an embodiment, the compound for use according to the fifth aspect of the invention is for use in bone marrow purging, by photodynamic therapy, in the treatment of leukaemia.

In an embodiment, the compound for use according to the fifth aspect of the invention is administered topically. In an embodiment, the compound for use according to the fifth aspect of the invention is administered orally. In an embodiment, the compound for use according to the fifth aspect of the invention is administered intravenously.

According to a sixth aspect of the invention there is provided the use of a compound according to the first aspect of the invention in photodynamic treatment for cosmetic purposes.

In an embodiment, the compound is used in the photodynamic treatment for cosmetic purposes of hypertrophic scars, acne scars, wrinkles (rhytides), actinically damaged skin (also known as photodamaged skin or sun damaged skin), rosacea, actinic keratosis, sebaceous gland hyperplasia, lentigines, hirsutism, telangiectasias, port wine stains, erythema, poikiloderma, melisma, dyschromia, hyperpigmentation, mottled or blotchy pigmentation, rough skin patches, poor skin texture, enlarged pores, and/or skin laxity.

In an embodiment, the compound is used in cosmetic photorejuvenation of skin by photodynamic treatment.

According to a seventh aspect of the invention there is provided a compound according to the first aspect of the invention for use in a diagnostic method practised on the human or animal body. In an embodiment, the diagnostic method is a method of diagnosing a condition which is caused by and/or exacerbated by the abnormal proliferation of cells. In an embodiment,
5 the condition which is caused by and/or exacerbated by the abnormal proliferation of cells is cancer.

As mentioned above, PpIX has a fluorescent ability, which enables the photodiagnosis (PD) of tumours. The production of a significantly greater level of PpIX in a significantly shorter time by using the compound according to the first aspect of the invention, therefore, can also
10 result in improved PD.

According to an eighth aspect of the invention there is provided the use of a compound according to the first aspect of the invention in a diagnostic method other than a diagnostic method practised on the human or animal body. In an embodiment, the diagnostic method is an *in vitro* diagnostic method. For example, PD could be used to enhance the histological
15 and/or microscopic analysis of tumours; this may help to further distinguish normal cells from abnormal cells in a specimen.

In an embodiment, the diagnostic method is a method of diagnosing a condition which is caused by and/or exacerbated by the abnormal proliferation of cells. In an embodiment, the condition which is caused by and/or exacerbated by the abnormal proliferation of cells is
20 cancer.

According to a ninth aspect there is provided the use of a compound according to the first aspect of the invention in the manufacture of a medicament for the treatment, by photodynamic therapy, of a condition which is caused by and/or exacerbated by the abnormal proliferation of cells. In an embodiment, the condition which is caused by and/or exacerbated
25 by the abnormal proliferation of cells is cancer.

A compound according to the first aspect of the invention may also be used in the manufacture of a medicament for the treatment, by photodynamic therapy, of any of the conditions referred to in connection with the fifth aspect of the invention.

According to a tenth aspect of the invention there is provided a method of treatment of a
30 human or animal patient suffering from or at risk of suffering from a condition which is caused by and/or exacerbated by the abnormal proliferation of cells, the method involving

administering to the patient a therapeutically effective amount of a compound according to the first aspect of the invention, and exposing a region of the patient containing the compound to light as part of a photodynamic therapy. In an embodiment, the condition which is caused by and/or exacerbated by the abnormal proliferation of cells is cancer.

- 5 A compound according to the first aspect of the invention may also be used in a method of treatment of a human or animal patient suffering from or at risk of suffering from any of the conditions referred to in connection with the fifth aspect of the invention, the method involving administering to the patient a therapeutically effective amount of a compound according to the first aspect of the invention, and exposing a region of the patient containing
10 the compound to light as part of a photodynamic therapy.

- Throughout the description and claims of this specification, the words "comprise" and "contain" and variations of the words, for example "comprising" and "comprises", mean "including but not limited to", and do not exclude other moieties, additives, components, integers or steps. Moreover the singular encompasses the plural unless the context otherwise
15 requires: in particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

- Preferred features of each aspect of the invention may be as described in connection with any of the other aspects. Other features of the invention will become apparent from the following
20 examples. Generally speaking the invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims and drawings). Thus features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example
25 described herein unless incompatible therewith. Moreover unless stated otherwise, any feature disclosed herein may be replaced by an alternative feature serving the same or a similar purpose.

Where upper and lower limits are quoted for a property, then a range of values defined by a combination of any of the upper limits with any of the lower limits may also be implied.

- 30 In this specification, references to compound properties such as optical rotations are – unless stated otherwise – to properties measured under ambient conditions, i.e. at atmospheric

pressure and at a temperature of from 16 to 22 or 25 °C, or from 18 to 22 or 25 °C, for example about 20 °C or about 25 °C.

The present invention will now be further described with reference to the following non-limiting examples, and the accompanying illustrative drawings, of which:

- 5 Figure 1 shows the results from a neutral red uptake assay to assess the level of inherent (dark) toxicity possessed by compound AP2-18 (**8**); *** indicates significance at the $P < 0.001$ level (student's t-test).

- Figure 2A shows the accumulation of PpIX fluorescence (+/- the standard error of the mean) in human dermal fibroblasts (84BR) over time following exposure to i) compound AP2-18 (**8**),
10 ii) ALA alone, iii) ALA and CP94 (**3**), iv) MAL alone, and v) MAL and CP94 (**3**).

- Figure 2B shows the results of a statistical analysis of the PpIX accumulation data in Table 1 and Figure 2A for human dermal fibroblasts (84BR); Figure 2B shows a statistical comparison of each of the three concentrations of compound AP2-18 (**8**) tested vs the other compounds tested (ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**) and the other concentrations of AP2-
15 18 (**8**)) (obtained by 2 way ANOVA with Bonferroni post-test to compare replicate means).

Figure 3A shows the accumulation of PpIX fluorescence (+/- the standard error of the mean) in human epithelial squamous cell carcinoma cells (A431) over time following exposure to i) compound AP2-18 (**8**), ii) ALA alone, iii) ALA and CP94 (**3**), iv) MAL alone, and v) MAL and CP94 (**3**).

- 20 Figure 3B shows the results of a statistical analysis of the PpIX accumulation data in Table 2 and Figure 3A for human epithelial squamous cell carcinoma cells (A431); Figure 3B shows a statistical comparison of each of the three concentrations of compound AP2-18 (**8**) tested vs the other compounds tested (ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**) and the other concentrations of AP2-18 (**8**)) (obtained by 2 way ANOVA with Bonferroni post-test to
25 compare replicate means).

Figure 4A shows the accumulation of PpIX fluorescence (+/- the standard error of the mean) in human glioblastoma cells (U87MG) over time following exposure to i) compound AP2-18 (**8**), ii) ALA alone, iii) ALA and CP94 (**3**), iv) MAL alone, and v) MAL and CP94 (**3**).

Figure 4B shows the results of a statistical analysis of the PpIX accumulation data in Table 3 and Figure 4A for human glioblastoma cells (U87MG); Figure 4B shows a statistical comparison of each of the three concentrations of compound AP2-18 (**8**) tested vs the other compounds tested (ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**) and the other concentrations of AP2-18 (**8**)) (obtained by 2 way ANOVA with Bonferroni post-test to compare replicate means).

Figure 5A shows the percentage PpIX photobleaching immediately post irradiation in human dermal fibroblasts (84BR) following exposure to ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**), and compound AP2-18 (**8**).

Figure 5B shows the effect on viability of human dermal fibroblasts (84BR) following exposure to ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**), and compound AP2-18 (**8**), and irradiation with red light.

Figure 5C shows the results of a statistical analysis of the cell viability data in Table 5 and Figure 5B for human dermal fibroblasts (84BR); Figure 5C shows a statistical comparison of each of the three concentrations of compound AP2-18 (**8**) tested vs the other compounds tested (ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**) and the other concentrations of AP2-18 (**8**)) (obtained by 1 way ANOVA with Tukey post-test comparing all pairs of columns).

Figure 6A shows the percentage PpIX photobleaching immediately post irradiation in human epithelial squamous cell carcinoma cells (A431) following exposure to ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**), and compound AP2-18 (**8**).

Figure 6B shows the effect on viability of human epithelial squamous cell carcinoma cells (A431) following exposure to ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**), and compound AP2-18 (**8**), and irradiation with red light.

Figure 6C shows the results of a statistical analysis of the cell viability data in Table 7 and Figure 6B for human epithelial squamous cell carcinoma cells (A431); Figure 6C shows a statistical comparison of each of the three concentrations of compound AP2-18 (**8**) tested vs the other compounds tested (ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**) and the other concentrations of AP2-18 (**8**)) (obtained by 1 way ANOVA with Tukey post-test comparing all pairs of columns).

Figure 7A shows the percentage PpIX photobleaching immediately post irradiation in human glioblastoma cells (U87MG) following exposure to ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**), and compound AP2-18 (**8**).

5 Figure 7B shows the effect on viability of human glioblastoma cells (U87MG) following exposure to ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**), and compound AP2-18 (**8**), and irradiation with red light.

Figure 7C shows the results of a statistical analysis of the cell viability data in Table 9 and Figure 7B for human glioblastoma cells (U87MG); Figure 7C shows a statistical comparison of each of the three concentrations of compound AP2-18 (**8**) tested vs the other compounds tested (ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**) and the other concentrations of AP2-18 (**8**)) (obtained by 1 way ANOVA with Tukey post-test comparing all pairs of columns).

Figure 8 shows the mean PpIX fluorescence measured in A431 cells following increasing doses (250, 500 or 1000 μ M) of (A) ALA +/- CP94, (B) MAL +/- CP94 and (C) AP2-18 after varying incubation periods (2, 3 or 4 hours); *, ** and *** indicates statistical significance at the 0.050, 0.010 and 0.001 levels respectively.

Figure 9 shows the mean PpIX fluorescence measured in A431 cells following increasing doses (250, 500 or 1000 μ M) of ALA +/- CP94, MAL +/- CP94 and AP2-18 after incubation periods of A(i) 2 hours, B(i) 3 hours and C(i) 4 hours with the corresponding statistical analysis for each time period presented in A(ii), B(ii) and C(ii) respectively.

20 Figure 10 shows the mean cell viability of A431 cells following increasing doses (250, 500 or 1000 mM) of (A) ALA +/- CP94, (B) MAL +/- CP94 and (C) AP2-18 after varying incubation periods (2, 3 or 4 hours); *, ** and *** indicates statistical significance at the 0.050, 0.010 and 0.001 levels respectively.

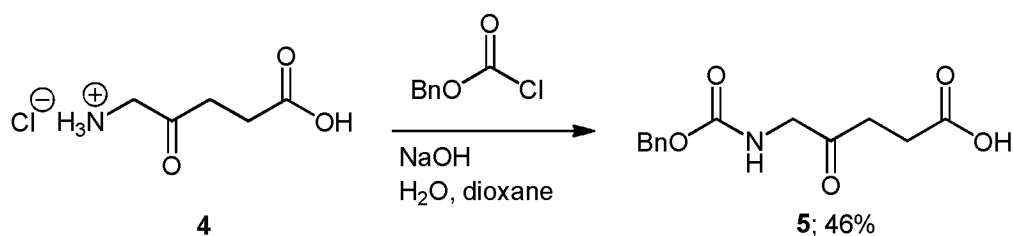
Figure 11 shows the mean cell viability of A431 cells following increasing doses (250, 500 or 1000 mM) of ALA +/- CP94, MAL +/- CP94 and AP2-18 after incubation periods of A(i) 2 hours, B(i) 3 hours and C(i) 4 hours with the corresponding statistical analysis for each time period presented in A(ii), B(ii) and C(ii) respectively; DLI stands for 'drug-light interval', i.e. the incubation period during which the cells have been exposed to the drug before irradiation takes place.

Examples

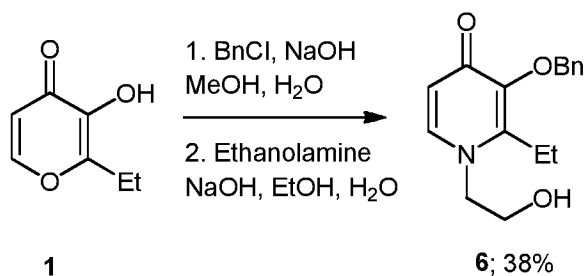
Example 1 - Synthesis of 1-(2-(5-amino-4-oxopentanoyloxy)ethyl)-2-ethyl-3,4-dihydropyridinium chloride hydrochloride (AP2-18), **8**

Synthesis of AP2-18 (**8**) was achieved via the coupling of benzyloxycarbonyl-protected aminolevulinic acid **5** with CP94 analogue **6**.

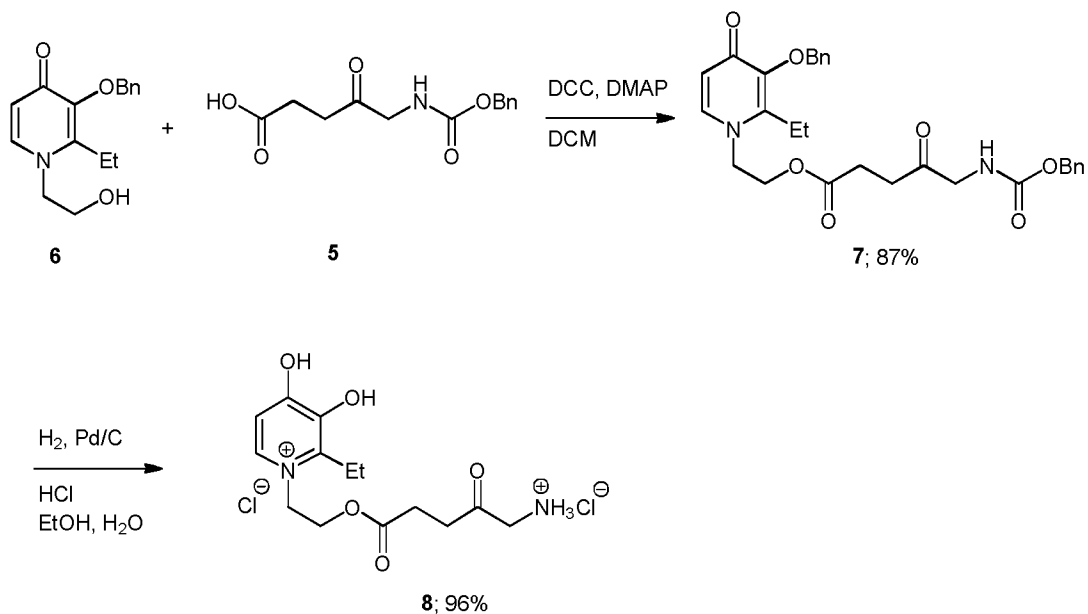
ALA-derivative **5** was synthesised by exposure of ALA.HCl (**4**) (obtained from Sigma-Aldrich) to benzyl chloroformate, under basic conditions, to give benzyloxy-protected ALA **5**.



The complementary coupling partner, CP94 analogue **6**, was synthesised from ethyl maltol (**1**) by benzyl protection then amination with ethanolamine.



Esterification of **5** and **6**, promoted by DCC/DMAP, proceeded smoothly to give the coupled product **7**, which was deprotected by hydrogenolysis to give the target compound AP2-18 (**8**):



Compound AP2-18 (**8**) is a compound according to the first aspect of the invention, and corresponds to the salt of formula (Ic).

Full experimental procedures for these steps are given below.

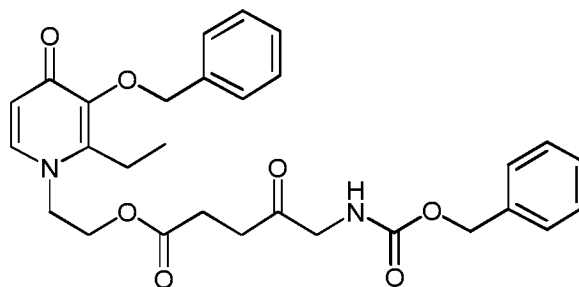
5 1A. ALA-derivative **5**

ALA-derivative **5** is a known compound which can, for example, be obtained via the procedure in Neuberger A. *et al.*, Biochemistry Journal, 1956, 64, 137-145.

1B. CP94 analogue **6**

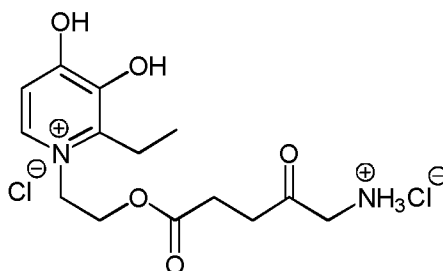
CP94 analogue **6** was prepared according to a previously published procedure (Dobbin, P.S., et al., J Med Chem, 1993. 36(17): p. 2448-58; Liu, Z. D. et al., J. Pharm. Pharmacol, 1999, 51, 555-564.

5 1C. 2-(3-(Benzyloxy)-2-ethyl-4-oxopyridin-1(4H)-yl)ethyl 5-(benzyloxycarbonylamino)-4-oxopentanoate, **7**



- 4-(Dimethylamino)pyridine (3.3 mg, 0.0274 mmol) was added to a stirred solution of 3-(benzyloxy)-2-ethyl-1-(2-hydroxyethyl)pyridin-4(1H)-one (**6**) (149 mg, 0.547 mmol), 5-(benzyloxycarbonylamino)-4-oxopentanoic acid (**5**) (145 mg, 0.547 mmol) and *N,N'*-dicyclohexylcarbodiimide (118 mg, 0.574 mmol) in dichloromethane (8 mL). After 24 h, the resulting suspension was filtered through cotton wool, eluting with dichloromethane. The filtrate was concentrated *in vacuo* and the residue was purified by flash chromatography on silica gel, eluting with ethyl acetate then methanol, to give the title compound **7** (247 mg, 87%) as a colourless oil, R_f 0.7 (MeOH); δ_H (300 MHz; $CDCl_3$) 7.46-7.20 (11H, m, Ar and Pyr 6-*H*), 6.40 (1H, d, J 9.0 Hz, Pyr 5-*H*), 5.97 (1H, br s, NH), 5.22 (2H, s, $PhCH_2$), 5.09 (2H, s, $PhCH_2$), 4.22 (2H, t, J 6.0 Hz, OCH_2CH_2), 4.10-3.95 (4H, m, $HNCH_2$ and OCH_2CH_2), 2.71-2.50 (6H, m, CH_3CH_2 and $C(O)CH_2CH_2$) and 0.99 (3H, t, J 7.0 Hz, CH_3); δ_C (75 MHz; $CDCl_3$) 204.7, 174.3, 172.3, 156.9, 146.2, 139.4, 138.0, 136.8, 129.1, 128.9, 128.8, 128.7, 128.5, 128.4, 128.3, 117.8, 73.3, 67.3, 63.3, 51.5, 50.9, 34.4, 27.9, 19.8 and 13.5.

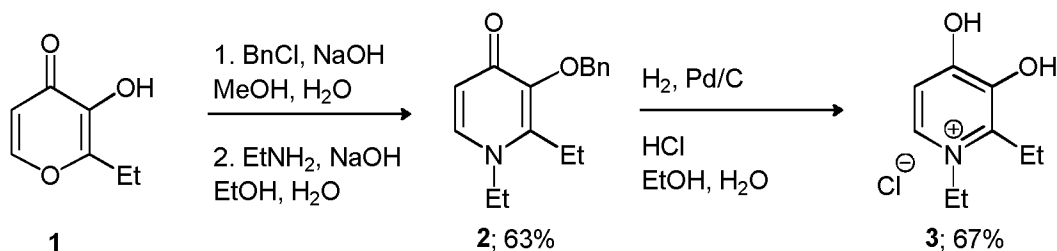
1D. 1-(2-(5-amino-4-oxopentanoyloxy)ethyl)-2-ethyl-3,4-dihydropyridinium chloride hydrochloride (AP2-18), **8**



- A stirred solution of 2-(3-(benzyloxy)-2-ethyl-4-oxopyridin-1(4*H*)-yl)ethyl 5-(benzyloxycarbonylamino)-4-oxopentanoate (**7**) (247 mg, 0.475 mmol) in 6:1 v/v ethanol:water (3.5 mL) was acidified to pH = 1 by addition of hydrochloric acid (37% aq.). Palladium on activated charcoal (11 mg, 10% w/w) was added, the reaction vessel was evacuated then filled with hydrogen and the reaction was stirred under hydrogen (at atmospheric pressure) for 2 h. The resulting suspension was filtered through Celite[®], eluting with ethanol and the filtrate was then concentrated *in vacuo* to give the product as a mixture of mono- and di-salts. Three cycles of dissolution in water, addition of hydrochloric acid (37% aq.) then concentration *in vacuo* gave the title compound **8** (169 mg, 96%) as a brown oil, δ_{H} (300 MHz; D₂O) 7.82 (1H, d, *J* 8.0 Hz, Ar 6-*H*), 6.92 (1H, d, *J* 8.0 Hz, Ar 5-*H*), 4.27 (2H, t, *J* 6.0 Hz, OCH₂CH₂), 3.91 (2H, s, H₃N⁺CH₂), 3.74 (2H, t, *J* 6.0 Hz, OCH₂CH₂), 2.80 (2H, q, *J* 7.0 Hz, CH₃CH₂), 2.66 (2H, t, *J* 6.0 Hz, C(O)CH₂), 2.45 (2H, t, *J* 6.0 Hz, C(O)CH₂) and 0.98 ppm (3H, t, *J* 7.0 Hz, CH₃); δ_{C} (75 MHz; D₂O) 204.3, 176.9, 158.6, 147.7, 142.5, 139.5, 111.0, 60.6, 57.8, 47.3, 34.6, 27.6, 20.1 and 11.3 ppm; *m/z* (ES⁺) 297.1445 (100%, [M-H-2Cl]⁺), C₁₄H₂₁N₂O₅ requires *M*, 297.1445.

Comparative Example 1 - Synthesis of CP94 (**3**)

- Compound CP94 (**3**) was prepared according to a previously published procedure (Dobbin, P.S., et al., J Med Chem, 1993. 36(17): p. 2448-58). Ethyl maltol (**1**) was benzyl protected and aminated to give **2**; and deprotection by hydrogenolysis gave CP94 (**3**), as shown below.



Example 2 - Experimental Testing of AP2-18 (8)

NB: Unless otherwise stated all data presented is the mean of three independent experiments each consisting of three internal repeats of each condition.

2A. Toxicity Testing

To establish if compound AP2-18 (**8**) possessed any inherent toxic properties, a 1000 μM test solution was prepared (the highest concentration to be tested in this study) in standard cell culture medium (minimum essential medium (MEM) containing 1% (v/v) fetal bovine serum (FBS), 200 mM L-glutamine, 200 U mL⁻¹ penicillin and 200 $\mu\text{g mL}^{-1}$ streptomycin). This was applied to MRC-5 (human embryonic lung fibroblast) cells, under reduced light conditions, and left for 4 hours (this time period was chosen as it is equivalent to that used in dermatological PDT clinics) in the dark and following this cell viability was determined using the neutral red uptake (NRU) assay. Neutral red is an inert dye actively taken up and stored by viable (living) cells, an action which is unable to be performed by non-viable cells, therefore the level of neutral red taken up is directly proportional to the number of viable cells present following a given exposure. Following uptake of the dye, cells are lysed and the level of neutral red quantified using a plate reader.

Control cells were incubated in standard cell culture medium. Cells were also exposed to 0.01% (v/v) hydrogen peroxide which acted as a positive control for the NRU assay. As can be seen from Figure 1, exposure to 0.01% (v/v) hydrogen peroxide resulted in a significant reduction in cell viability. Treatment with AP2-18 (**8**) did result in a very slight reduction in the number of viable cells, however on statistical analysis this was not found to be significantly different to control cells incubated in standard cell culture medium. AP2-18 (**8**), therefore, is not inherently toxic to MRC-5 (lung fibroblast) cells when compared to cells only exposed to cell medium.

2B. PpIX Fluorescence Accumulation

The level of protoporphyrin IX (PpIX) accumulation was monitored using a well-established previously validated fluorescence based assay described in Blake, E. *et al.*, Photochem Photobiol, 2011, 87(6), 1419-26; Blake, E. *et al.*, Photochem Photobiol, 2010, 86(5), 1154-60; 5 Curnow, A. *et al.*, J Environ Pathol Toxicol Oncol, 2007, 26(2), 89-103; and Pye, A. *et al.*, J Cancer Res Clin Oncol, 2008, 134(8), 841-9.

Briefly, cells were seeded at 2×10^4 cells per well in a 96 well plate and left to adhere overnight. Test solutions were prepared on the day of the assay and applied to the cells. The level of PpIX produced was monitored using a multi-well fluorescent plate reader with a 400 10 (± 30) nm excitation filter and a 645 (± 40) nm emission filter, with the level of fluorescence produced being directly proportional to the level of PpIX present. Readings were taken hourly for 6 hours and were conducted under low light conditions to reduce photobleaching of PpIX.

To evaluate the ability of AP2-18 (**8**) to cause an increase in PpIX accumulation within cells a series of concentrations were prepared (250 μ M; 500 μ M; 1000 μ M) which reflect those 15 previously used by our group (see citations mentioned above). These were tested alongside equimolar concentrations of ALA, ALA and CP94 (**3**), MAL, and MAL and CP94 (**3**), with all test compounds being investigated in human dermal fibroblasts (84BR; Figures 2A and 2B), human epithelial squamous cell carcinoma cells (A431; Figures 3A and 3B) and human glioblastoma cells (U87MG; Figures 4A and 4B).

20 The results are given in the tables below: Table 1 shows the results for the tests with human dermal fibroblasts (84BR) corresponding to Figures 2A and 2B); Table 2 shows the results for the tests with human epithelial squamous cell carcinoma cells (A431) corresponding to Figures 3A and 3B; and Table 3 shows the results for the tests with human glioblastoma cells (U87MG) corresponding to Figures 4A and 4B.

Exposure Time (hours)	Drug								
	ALA (250 μ M)								
0	0	-3	-3	-6.33	-3.33	-4.33	0.33	2.33	3.33
1	8.33	7.33	4.33	-0.33	0.67	0.67	5	8	7
2	15	14	13	14.67	13.67	12.67	3	5	5
3	23	20	20	28	26	27	4.33	8.33	6.33
4	23	25	21	39.67	34.67	38.67	8	10	9
5	25	26	22	53	49	52	6.67	9.67	9.67
6	25.67	28.67	25.67	62.33	56.33	61.33	9.33	11.33	10.33

Exposure Time (hours)	Drug								
	ALA (500 μ M)								
0	-1.33	-9.33	-5.33	-9	-4	-6	-2.67	-4.67	-15.67
1	9.33	5.33	5.33	-1	1	-1	-4.67	8.33	-3.67
2	29.67	25.67	23.67	25.67	25.67	23.67	8.33	21.33	8.33
3	51	52	48	50	51	48	20	36	19
4	66.67	67.67	64.67	74	73	70	37.67	55.67	35.67
5	84.33	87.33	85.33	99.33	97.33	93.33	50	68	48
6	97	108	105	122.33	119.33	115.33	63	81	59

Exposure Time (hours)	Drug								
	ALA (1000 μ M)								
0	-2	-11	-11	-4.67	-4.67	-3.67	-8.33	-9.33	-8.33
1	12.67	9.67	7.67	0	4	8	-4.33	-1.33	-1.33
2	48.67	43.67	41.67	31.33	37.33	44.33	13	14	12
3	85.67	81.67	80.67	65	73	84	35.33	35.33	30.33
4	117.67	115.67	113.67	95.67	105.67	115.67	57.33	56.33	47.33
5	154.67	154.67	149.67	131.33	142.33	158.33	79.33	77.33	69.33
6	186	191	186	163	175	195	104.33	100.33	89.33

Exposure Time (hours)	Drug								
	ALA (250 μ M) + CP94 (250 μ M)								
0	-4	-5	0	-9	-4	-12	-6.33	-5.33	-5.33
1	29	28	27	16	15	13	11.67	13.67	11.67
2	62	64	66	52.33	48.33	46.33	34.67	37.67	36.67
3	95	99	102	84.67	76.67	74.67	52	58	56
4	121.33	126.33	129.33	114.33	100.33	99.33	71.33	77.33	73.33
5	150	155	155	141.33	126.33	124.33	85.67	91.67	89.67
6	172.67	179.67	185.67	169.33	149.33	147.33	102.33	107.33	103.33

Exposure Time (hours)	Drug								
	ALA (500 μ M) + CP94 (500 μ M)								
0	-0.33	-3.33	4.67	-18.67	-7.67	-8.67	-7.67	-1.67	-0.67
1	40.33	38.33	35.33	-8	0	4	10.33	14.33	16.33
2	87.33	89.33	87.33	7.33	20.33	24.33	40.67	46.67	48.67
3	134.67	145.67	138.67	17.67	34.67	46.67	71.67	74.67	77.67
4	177.33	190.33	181.33	24	50	61	102.33	105.33	107.33
5	224.67	241.67	230.67	31	62	78	128.67	131.67	136.67
6	265	284	274	35.67	71.67	94.67	155	155	159

Exposure Time (hours)	Drug								
	ALA (1000 μ M) + CP94 (1000 μ M)								
0	1.67	-0.33	3.67	-10.67	-8.67	-7.67	-19.67	-19.67	-12.67
1	50	40	39	20	23	20	-1.67	1.33	6.33
2	101.33	101.33	95.33	70.67	73.67	70.67	17.67	29.67	35.67
3	169.33	167.33	158.33	122	123	119	39.33	55.33	65.33
4	226.33	224.33	210.33	170.67	171.67	162.67	58.33	78.33	91.33
5	292.67	287.67	270.67	222.67	224.67	212.67	77.33	101.33	116.33
6	360.67	352.67	330.67	268	273	259	98.33	126.33	136.33

Exposure Time (hours)	Drug								
	MAL (250 μ M)								
0	-8.33	-0.33	0.67	-12.67	-7.67	-5.67	-12.33	-11.33	-7.33
1	0	3	0	-13	-8	-9	-11	-10	-7
2	-5.33	-0.33	-2.33	-12	-7	-7	-13	-10	-9
3	-6.33	-0.33	-1.33	-10.67	-5.67	-5.67	-11	-9	-8
4	-5	-1	-1	-11	-7	-6	-12	-9	-10
5	-5	1	1	-8.67	-4.67	-3.67	-12.33	-9.33	-7.33
6	-4	0	-1	-10	-5	-5	-10	-10	-8

Exposure Time (hours)	Drug								
	MAL (500 μ M)								
0	-11	-8	-4	-10.33	-7.33	-2.33	-23.67	1.33	14.33
1	-8.67	-6.67	-6.67	-11	-11	-11	-21	2	6
2	-8.67	-4.67	-0.67	-4.33	-4.33	-4.33	-18.33	1.67	5.67
3	-6.33	-3.33	-0.33	2	2	2	-18.67	2.33	3.33
4	-5.67	-0.67	1.33	1.33	4.33	4.33	-12.33	3.67	9.67
5	-3.67	1.33	0.33	9.67	9.67	9.67	-7.67	5.33	7.33
6	-4	-1	1	10.67	11.67	11.67	-4.33	8.67	10.67

Exposure Time (hours)	Drug								
	MAL (1000 μ M)								
0	-2.33	8.67	7.67	-23.67	-17.67	-17.67	5	14	-7
1	1	7	6	-22	-11	-22	-9.33	-2.33	0.67
2	8.67	14.67	14.67	-8	4	-6	-5.67	2.33	3.33
3	16.33	22.33	20.33	11.67	21.67	19.67	2	10	9
4	21.33	23.33	27.33	27.67	36.67	33.67	9.33	14.33	14.33
5	29	28	32	39	51	49	14	23	20
6	34	32	38	53.33	62.33	63.33	14.67	26.67	20.67

Exposure Time (hours)	Drug								
	MAL (250 μ M) + CP94 (250 μ M)								
0	-0.33	-2.33	-3.33	-12.33	-7.33	-3.33	5	5	5
1	16	12	9	-2	2	3	12.67	10.67	13.67
2	28	27	23	9	14	15	19.33	17.33	22.33
3	37.33	37.33	35.33	18.67	25.67	26.67	24	24	30
4	48.33	48.33	44.33	27.33	32.33	34.33	33	31	37
5	60.33	59.33	56.33	39.67	43.67	46.67	38	35	43
6	74.33	68.33	66.33	47	54	52	43	42	51

Exposure Time (hours)	Drug								
	MAL (500 μ M) + CP94 (500 μ M)								
0	-11.67	-6.67	3.33	-12	-8	-10	-4.67	-1.67	0.33
1	16.33	16.33	15.33	-2.33	1.67	-0.33	4.67	8.67	10.67
2	35.67	37.67	39.67	19.67	24.67	17.67	21.67	24.67	25.67
3	58.33	59.33	62.33	40	40	35	32.67	33.67	40.67
4	77.33	78.33	79.33	54	54	48	45	48	53
5	103	101	103	72.33	71.33	62.33	59	59	66
6	123.67	120.67	121.67	83	85	77	70.67	68.67	76.67

Exposure Time (hours)	Drug								
	MAL (1000 μ M) + CP94 (1000 μ M)								
0	-6.67	-12.67	-16.67	-34	0	-8	-16.33	-16.33	-20.33
1	16	20	12	-11	10	11	5	10	0
2	46.67	45.67	37.67	14	35	34	30	51	31
3	79	76	68	34.33	50.33	52.33	47	77	55
4	107.67	105.67	93.67	52	67	67	69.33	103.33	78.33
5	140	139	120	66.67	78.67	81.67	85.67	127.67	94.67
6	170.67	164.67	150.67	87.67	88.67	92.67	103	152	113

Exposure Time (hours)	Drug								
	AP2-18 (250 μ M)								
0	-11	-11	-7	-12.33	-10.33	-14.33	-1.67	-4.67	-2.67
1	28.67	30.67	33.67	16.67	19.67	17.67	49	40	46
2	84	73	89	70.33	68.33	73.33	119	108	115
3	143	123	152	124	124	126	194.67	179.67	183.67
4	191.67	166.67	203.67	174.67	174.67	181.67	272.67	255.67	261.67
5	245.33	216.33	263.33	228	231	237	354.33	335.33	343.33
6	302.33	262.33	321.33	283.33	282.33	288.33	422.67	396.67	406.67

Exposure Time (hours)	Drug								
	AP2-18 (500 μ M)								
0	-8.33	-6.33	-7.33	-12.33	-11.33	-12.33	-3.33	-1.33	0.67
1	34.67	33.67	35.67	20.67	17.67	11.67	62.67	55.67	53.67
2	101.67	96.67	99.67	77.33	65.33	57.33	165.67	144.67	139.67
3	169.67	160.67	168.67	142.33	118.33	105.33	276.33	236.33	231.33
4	236.67	223.67	231.67	205	171	149	391	336	329
5	311.33	293.33	304.33	269	223	197	522.33	450.33	440.33
6	387.67	363.67	374.67	332	275	240	627.67	543.67	529.67

Exposure Time (hours)	Drug								
	AP2-18 (1000 μ M)								
0	-5.67	-12.67	-5.67	-24.33	-20.33	-9.33	-6.33	-0.33	-1.33
1	29.33	33.33	38.33	-2.33	3.67	19.67	52.67	58.67	57.67
2	84.67	94.67	96.67	39	45	67	144.67	150.67	149.67
3	144.33	156.33	157.33	77.33	81.33	117.33	241.33	246.33	245.33
4	203.67	218.67	213.67	114	119	166	341.67	348.67	347.67
5	265.33	287.33	277.33	158	160	220	457	464	462
6	330.67	358.67	341.67	196.33	196.33	270.33	549	555	557

Table 1: PpIX accumulation in human dermal fibroblasts (84BR)

Exposure Time (hours)	Drug								
	ALA (250 μ M)								
0	-9	-5	-4	2.67	2.67	7.67			
1	-6	-3	-2	1.67	1.67	4.67			
2	-1.33	1.67	3.67	10	9	11			
3	3	8	8	18	19	18			
4	13.33	17.33	17.33	28	28	28			
5	20.33	26.33	26.33	35.67	36.67	35.67			
6	26.33	32.33	30.33	44.67	47.67	44.67			

Exposure Time (hours)	Drug								
	ALA (500 μ M)								
0	-16.67	-15.67	-19.67	5	2	10			
1	-15.33	-13.33	-15.33	7.33	3.33	7.33			
2	-3.67	-1.67	-2.67	15.33	12.33	19.33			
3	7	9	6	27	24	32			
4	22.67	25.67	27.67	38	36	43			
5	39.67	42.67	45.67	49.33	49.33	51.33			
6	52.33	55.33	61.33	61.67	62.67	62.67			

Exposure Time (hours)	Drug								
	ALA (1000 μ M)								
0	-15.67	-5.67	1.33	0.67	-0.33	-0.33			
1	-11	-6	2	2.67	1.67	3.67			
2	1.33	9.33	14.33	12.33	15.33	16.33			
3	14.33	25.33	26.33	27.33	28.33	32.33			
4	32.33	45.33	43.33	38.33	38.33	45.33			
5	50.67	63.67	60.67	51.67	54.67	57.67			
6	63	79	72	65	68	75			

Exposure Time (hours)	Drug								
	ALA (250 μ M) + CP94 (250 μ M)								
0	-7.33	-7.33	-11.33	1.33	-0.67	-3.67			
1	3	4	0	12	9	10			
2	26.67	24.67	19.67	37	34	39			
3	46	46	38	62	58	67			
4	70.67	71.67	61.67	87.33	77.33	89.33			
5	97.33	99.33	87.33	109	101	111			
6	118.33	121.33	110.33	135.33	128.33	140.33			

Exposure Time (hours)	Drug								
	ALA (500 μ M) + CP94 (500 μ M)								
0	-11.67	-9.67	-5.67	0	7	0			
1	9.67	6.67	9.67	11.33	16.33	14.33			
2	38.67	33.67	37.67	38	44	40			
3	69.33	61.33	69.33	68	73	71			
4	108	95	102	95	100	94			
5	145.67	131.67	140.67	123.67	127.67	121.67			
6	177.67	160.67	171.67	152	155	152			

Exposure Time (hours)	Drug								
	ALA (1000 μ M) + CP94 (1000 μ M)								
0	-19.33	-15.33	-19.33	-4	-2	2			
1	-9	-7	-8	11.33	15.33	15.33			
2	4	4	5	45	46	50			
3	15.67	17.67	15.67	76.67	77.67	81.67			
4	35	34	38	103.67	100.67	110.67			
5	54.67	55.67	56.67	134.67	127.67	143.67			
6	68	71	75	163	159	171			

Exposure Time (hours)	Drug									
	MAL (250 μ M)									
0	-10.67	-3.67	-2.67	-5.33	-8.33	-10.33	-12.33	-15.33	-20.33	
1	3.67	3.67	5.67	-0.33	-3.33	-7.33	-9.67	-9.67	-14.67	
2	-5	0	1	-0.33	-5.33	-6.33	-11	-10	-16	
3	-4.67	-0.67	1.33	0.67	-3.33	-7.33	-11.67	-9.67	-14.67	
4	-4.67	-2.67	-2.67	-2.67	-3.67	-8.67	-11.67	-10.67	-15.67	
5	-3.67	-1.67	-0.67	1	-3	-6	-11	-8	-16	
6	-3.33	-2.33	-2.33	4.33	-2.67	-6.67	-13	-12	-16	

Exposure Time (hours)	Drug									
	MAL (500 μ M)									
0	-9.33	-11.33	-1.33	-14	-16	-13	5.33	-6.67	3.33	
1	-1	-12	-4	-10.33	-12.33	-13.33	5.33	-2.67	1.33	
2	-4.33	-7.33	4.67	-5.67	-5.67	-7.67	8.67	-2.33	1.67	
3	-3.67	-6.67	5.33	-2.67	0.33	-2.67	7.67	-2.33	1.67	
4	-4.33	-7.33	3.67	0.67	3.67	1.67	9	0	2	
5	-1.33	-6.33	6.67	4.33	7.33	7.33	10.67	0.67	4.67	
6	-3.33	-5.33	6.67	8	11	8	8.67	0.67	2.67	

Exposure Time (hours)	Drug								
	MAL (1000 μ M)								
0	-17.33	-10.33	-10.33	-1.67	2.33	3.33			
1	-3	2	-1	-0.33	2.67	1.67			
2	21	28	21	9.67	10.67	11.67			
3	45	50	42	22.67	25.67	20.67			
4	70	74	64	34.33	39.33	30.33			
5	97.67	99.67	88.67	47.33	53.33	42.33			
6	122.67	124.67	108.67	62.33	65.33	55.33			

Exposure Time (hours)	Drug								
	MAL (250 μ M) + CP94 (250 μ M)								
0	-5.67	-8.67	-4.67	-127	-127	-127	6	11	3
1	27.67	15.67	17.67	5.67	5.67	9.67	13	15	5
2	36.33	30.33	35.33	16.67	14.67	20.67	10.33	23.33	13.33
3	51	42	50	28	24	31	21.33	30.33	19.33
4	65.67	53.67	61.67	35.67	34.67	39.67	27.33	37.33	26.33
5	77.67	63.67	74.67	49.33	47.33	52.33	33.33	45.33	34.33
6	95	80	92	54.33	55.33	60.33	39	51	38

Exposure Time (hours)	Drug								
	MAL (500 μ M) + CP94 (500 μ M)								
0	-11	-16	-12	-134	-134	-134	0.33	-5.67	-4.67
1	18	13	15	10.33	-1.67	-6.67	6	2	0
2	38	33	39	31.33	19.33	7.33	17.67	16.67	14.67
3	57	54	61	54.33	40.33	19.33	26	27	24
4	73.67	72.67	79.67	68.33	55.33	27.33	39.33	36.33	33.33
5	93.33	95.33	103.33	87	75	39	50.33	50.33	43.33
6	112.33	119.33	123.33	108.33	91.33	48.33	51.67	57.67	51.67

Exposure Time (hours)	Drug								
	MAL (1000 μ M) + CP94 (1000 μ M)								
0	-12.67	-8.67	-0.67	19.67	11.67	6.67			
1	-6	-2	-2	26.67	16.67	10.67			
2	13	18	15	55.67	44.67	37.67			
3	34.33	40.33	40.33	82.67	74.67	63.67			
4	51.33	61.33	60.33	110.67	96.67	86.67			
5	76.33	84.33	86.33	114.67	117.67	111.67			
6	93.67	107.67	104.67	144	147	137			

Exposure Time (hours)	Drug								
	AP2-18 (250 μ M)								
0	-1.33	-1.33	-3.33	0.67	-1.33	-3.33	9.67	5.67	5.67
1	6.33	5.33	6.33	20.67	19.67	17.67	23	23	22
2	20.33	17.33	19.33	43.67	42.67	41.67	44.67	54.67	48.67
3	32	30	30	72.33	69.33	69.33	67	80	79
4	42.33	42.33	46.33	100.33	96.33	97.33	89.67	111.67	111.67
5	53.67	52.67	57.67	127.67	120.67	120.67	113.67	144.67	141.67
6	71.33	65.33	71.33	152.33	143.33	145.33	150.67	186.67	181.67

Exposure Time (hours)	Drug								
	AP2-18 (500 μ M)								
0	10.67	10.67	9.67	9.67	1.67	5.67	19.67	11.67	13.67
1	21.33	21.33	21.33	33.67	22.67	28.67	33	32	29
2	34.33	35.33	33.33	57.67	49.67	55.67	58.67	69.67	58.67
3	46	50	46	86.33	78.33	85.33	89	101	85
4	59.33	67.33	62.33	114.33	109.33	114.33	119.67	139.67	118.67
5	71.67	82.67	73.67	137.67	136.67	140.67	151.67	177.67	146.67
6	88.33	99.33	95.33	163.33	158.33	164.33	196.67	226.67	188.67

Exposure Time (hours)	Drug								
	AP2-18 (1000 μ M)								
0	26.67	22.67	34.67	9.67	9.67	16.67	31.67	28.67	29.67
1	41.33	38.33	49.33	33.67	34.67	36.67	49	51	51
2	58.33	58.33	69.33	58.67	58.67	63.67	78.67	97.67	93.67
3	76	79	92	89.33	86.33	88.33	109	135	134
4	96.33	100.33	116.33	117.33	114.33	118.33	144.67	180.67	182.67
5	113.67	119.67	140.67	145.67	139.67	141.67	177.67	221.67	225.67
6	136.33	147.33	168.33	167.33	163.33	164.33	226.67	276.67	286.67

Table 2: PpIX accumulation in human epithelial squamous cell carcinoma cells (A431) - missing data is due to an infection present in these wells in this replicate and therefore data was discarded

Exposure Time (hours)	Drug								
	ALA (250 μ M)								
0	-1.33	-0.33	-1.33	-2.33	-4.33	-2.33	-3	-5	-4
1	6.67	6.67	6.67	26.67	21.67	27.67	0	0	1
2	27.67	24.67	24.67	71	66	77	14.67	13.67	15.67
3	44.33	43.33	45.33	120	114	132	27.67	26.67	28.67
4	67	63	67	173.33	164.33	190.33	42.33	42.33	44.33
5	84.33	82.33	84.33	213	203	230	54.67	53.67	56.67
6	102	100	102	258	250	281	69	69	70

Exposure Time (hours)	Drug								
	ALA (500 μ M)								
0	-11	-10	-13	-5.33	-3.33	-3.33	-3.67	-5.67	-5.67
1	4.33	6.33	5.33	29.33	36.33	33.33	5.67	6.67	2.67
2	40.33	42.33	43.33	81.33	97.33	91.33	28	28	26
3	76.33	79.33	80.33	144.33	164.33	153.33	55.67	53.67	49.67
4	118.33	122.33	125.33	212	248	230	76.33	78.33	73.33
5	159.67	163.67	170.67	269.67	306.67	285.67	101.33	103.33	95.33
6	202	202	211	345.33	389.33	366.33	128	129	119

Exposure Time (hours)	Drug								
	ALA (1000 μ M)								
0	-8	-9	-1	-6.33	-4.33	2.67	-5	-5	-6
1	15.67	14.67	18.67	43	42	43	7	7	8
2	53.33	56.33	60.33	113	106	105	26	31	29
3	93.67	93.67	99.67	188	178	169	49	54	52
4	135	141	144	266.33	258.33	245.33	67.67	74.67	73.67
5	181.67	187.67	189.67	329.33	319.33	304.33	90.67	99.67	95.67
6	224.67	229.67	232.67	414.33	404.33	381.33	114.33	123.33	117.33

Exposure Time (hours)	Drug								
	ALA (250 μ M) + CP94 (250 μ M)								
0	-2.67	-5.67	-8.67	-5	-7	-12	-8.33	-6.33	-6.33
1	18.67	14.67	12.67	33	33	30	5.33	6.33	6.33
2	47.67	49.67	43.67	86.33	94.33	92.33	26.67	30.67	31.67
3	77.33	78.33	68.33	148.67	162.67	158.67	44.67	54.67	51.67
4	107.33	111.33	92.33	213	239	226	61.67	70.67	70.67
5	139.33	142.33	118.33	262	297	278	79	88	90
6	165	170	144	325.33	363.33	341.33	97.67	108.67	107.67

Exposure Time (hours)	Drug								
	ALA (500 μ M) + CP94 (500 μ M)								
0	-4	0	0	-18.33	-14.33	-11.33	-3.67	-7.67	-4.67
1	25.33	19.33	15.33	36	43	44	11.67	11.67	11.67
2	67.67	50.67	42.67	104	121	118	38.67	36.67	38.67
3	105.67	81.67	67.67	180.67	201.67	197.67	63.67	62.67	64.67
4	154.67	116.67	96.67	263.67	292.67	282.67	87.33	81.33	84.33
5	201.67	154.67	130.67	333.33	361.33	348.33	112.67	110.67	110.67
6	245.33	188.33	156.33	418	446	438	137.33	133.33	136.33

Exposure Time (hours)	Drug								
	ALA (1000 μ M) + CP94 (1000 μ M)								
0	-10.67	-10.67	-15.67	-18.67	-17.67	-16.67	-8.67	-9.67	-9.67
1	3.67	12.67	13.67	58.67	45.67	59.67	8.67	3.67	1.67
2	25	49	47	146.33	122.33	154.33	33.67	30.67	24.67
3	44	77	77	243	205	248	56.33	53.33	45.33
4	69.67	114.67	116.67	340	294	349	78	73	63
5	95.67	152.67	154.67	413	360	419	102.67	93.67	83.67
6	118.67	185.67	189.67	509.67	448.67	516.67	123.33	114.33	103.33

Exposure Time (hours)	Drug								
	MAL (250 μ M)								
0	-11.33	-1.33	-2.33	-20	-21	-22	-12.67	-12.67	-10.67
1	4	-7	11	-14	-16	-15	-10	-7	-7
2	2.67	-2.33	4.67	-10.67	-12.67	-14.67	-10.67	-8.67	-7.67
3	8	6	12	-6.67	-10.67	-9.67	-9.33	-7.33	-9.33
4	16.67	13.67	20.67	-5.33	-6.33	-6.33	-9.33	-6.33	-7.33
5	27.33	22.33	29.33	1	0	-2	-9	-7	-9
6	32	25	34	1.67	4.67	-1.33	-9.67	-6.67	-7.67

Exposure Time (hours)	Drug								
	MAL (500 μ M)								
0	-11	-23	-21	-25.67	-22.67	-26.67	-5	-10	-3
1	23.33	10.33	6.33	-20	-16	-17	2	-4	1
2	40.33	33.33	29.33	-5	-4	-4	7	1	7
3	70	60	53	7	11	10	13	11	12
4	96	82	74	15	21	19	22.33	21.33	19.33
5	123.67	108.67	98.67	27.33	33.33	33.33	29.67	28.67	22.67
6	149	129	117	39.33	47.33	44.33	35	31	27

Exposure Time (hours)	Drug								
	MAL (1000 μ M)								
0	-7.67	-5.67	-6.67	-25.67	-19.67	-2.67	-7.33	-9.33	-1.33
1	20.67	21.67	19.67	14	17	37	2	1	11
2	67	70	64	69.33	72.33	87.33	24.33	22.33	27.33
3	107.33	109.33	103.33	137.33	135.33	147.33	42.33	41.33	49.33
4	148.67	151.67	143.67	204	204	210	59.67	60.67	67.67
5	190.67	192.67	186.67	259.33	255.33	259.33	79.33	78.33	89.33
6	232.33	231.33	223.33	334.33	325.33	324.33	101.67	97.67	112.67

Exposure Time (hours)	Drug								
	MAL (250 μ M) + CP94 (250 μ M)								
0	-0.33	-14.33	-5.33	-19.67	-22.67	-21.67	0.67	9.67	5.67
1	44	32	26	-13	-4	-5	11.67	19.67	14.67
2	72	58	50	5.33	4.33	2.33	17.67	30.67	23.67
3	95.67	86.67	68.67	15.67	14.67	12.67	23.67	36.67	28.67
4	120	115	88	21	23	19	33.67	43.67	35.67
5	148.67	142.67	109.67	33.33	35.33	32.33	36.33	50.33	44.33
6	164.33	166.33	128.33	39.67	41.67	38.67	43.33	54.33	44.33

Exposure Time (hours)	Drug								
	MAL (500 μ M) + CP94 (500 μ M)								
0	8.33	-19.67	-19.67	-6.33	-10.33	-27.33	9	1	1
1	21.33	-0.67	1.33	1.67	0.67	-7.33	9.67	20.67	15.67
2	22.67	3.67	11.67	22	19	15	15	36	33
3	37.67	14.67	23.67	40	36	35	19.33	45.33	43.33
4	50	24	34	58.67	50.67	48.67	29.67	54.67	54.67
5	65.33	33.33	47.33	78	70	63	35.33	63.33	67.33
6	78.67	43.67	56.67	94.67	82.67	81.67	40	70	76

Exposure Time (hours)	Drug								
	MAL (1000 μ M) + CP94 (1000 μ M)								
0	-6	-6	-3	1.33	5.33	4.33	-3	-3	-3
1	2.67	4.67	2.67	54.33	52.33	39.33	7	11	6
2	30	31	28	120.67	113.67	82.67	28.33	33.33	31.33
3	57.67	56.67	45.67	192.67	179.67	131.67	47.33	59.33	50.33
4	80	83	72	270	253	186	62	82	73
5	107.33	114.33	93.33	325.67	305.67	226.67	78.67	101.67	93.67
6	135.33	141.33	113.33	407.67	379.67	284.67	101.33	124.33	117.33

Exposure Time (hours)	Drug								
	AP2-18 (250 μ M)								
0	5.3	-1.7	-111.7	-6.67	-4.67	0	-1.33	8.67	0
1	50.3	57.3	66.3	53.67	50.67	55.67	57.33	52.33	56.33
2	114.3	128.3	146.3	125.67	126.67	129.67	130.67	128.67	129.67
3	172	199	221	195	196	199	189.33	195.33	184.33
4	230	267	308	268	270	275	254	273	253
5	293.7	331.7	383.7	319	326	328	313.67	346.67	308.67
6	346.3	373.3	437.3	370	371	380	388.33	447.33	379.33

Exposure Time (hours)	Drug								
	AP2-18 (500 μ M)								
0	9.3	9.3	12.3	2.33	-1.67	7.33	1.67	5.67	8.67
1	101.3	96.3	88.3	79.67	71.67	96.67	66.33	74.33	77.33
2	211.3	203.3	180.3	181.67	168.67	207.67	166.67	176.67	182.67
3	312	308	267	279	267	308	251.33	271.33	273.33
4	421	417	371	392	380	425	353	374	373
5	540.7	526.7	470.7	473	455	506	460.67	479.67	480.67
6	655.3	637.3	561.3	555	538	581	582.33	610.33	599.33

Exposure Time (hours)	Drug								
	AP2-18 (1000 μ M)								
0	46.3	31.3	46.3	14.33	17.33	24.33	39.67	21.67	28.67
1	144.3	126.3	107.3	100.67	104.67	112.67	116.33	101.33	119.33
2	271.3	242.3	194.3	217.67	219.67	228.67	245.67	229.67	258.67
3	386	351	270	320	337	341	354.33	333.33	369.33
4	519	469	361	447	468	469	478	456	499
5	642.7	580.7	436.7	534	546	559	601.67	581.67	633.67
6	762.3	688.3	528.3	623	650	651	753.33	718.33	792.33

Table 3: PpIX accumulation in human glioblastoma cells (U87MG)

Accumulation of PpIX fluorescence produced by each of the prodrugs investigated (AP2-18 (8), ALA, ALA and CP94 (3), MAL, and MAL and CP94 (3)) increased over time in each of the three cell types examined. Novel compound AP2-18 (8), which is a compound according to the first aspect of the invention, was found to significantly increase PpIX accumulation in all three cell types, above and beyond that achieved with ALA or MAL administration either alone or in combination with the iron chelator CP94 (3). These findings suggested that *in vitro* AP2-18 (8) represents a compound which is able to produce a significantly greater level of PpIX in a potentially significantly shorter time, and hence that AP2-18 (8) has the potential to substantially improve PpIX-induced PDT. Further experimentation to determine whether this significant increase in PpIX accumulation could be translated into increased cell kill on irradiation was undertaken.

2C. PDT Efficacy

To assess the effect of AP2-18 (8) on PpIX-induced PDT efficacy, the same three cell types were exposed to equimolar concentrations of ALA, ALA and CP94 (3), MAL, MAL and CP94 (3), and AP2-18 (8) (as described previously) and incubated in the dark for 4 hours. The level of PpIX accumulation was then quantified as before, prior to irradiation with red light (37 J/cm²; 635 ± 2 nm; Aktelite, Galderma, UK). The level of PpIX remaining immediately post irradiation was also ascertained and the change in PpIX level (PpIX photobleaching) was calculated as a percentage (Figures 5A, 6A and 7A). Cell viability was then assessed using the NRU assay (as described previously) with these data being normalised against the blank control cells (which were exposed to normal cell media) and presented as a percentage of viable cells (Figures 5B, 6B and 7B). The results of the statistical analyses which were subsequently undertaken are presented in Figures 5C, 6C and 7C respectively.

The results of the tests with human dermal fibroblasts (84BR) are given in Tables 4 and 5 below and in Figures 5A, 5B and 5C. The results of the tests with human epithelial squamous cell carcinoma cells (A431) are given in Tables 6 and 7 below and shown in Figures 6A, 6B and 6C. The results of the tests with human glioblastoma cells (U87MG) are given in Tables 8 and 9 below and shown in Figures 7A, 7B and 7C.

ALA (250 μ M)	ALA (500 μ M)	ALA (1000 μ M)	ALA (250 μ M) + CP94 (250 μ M)	ALA (500 μ M) + CP94 (500 μ M)	ALA (1000 μ M) + CP94 (1000 μ M)	MAL(250 μ M)
57.89474	61.57407	54.84728	57.2327	52.15947	42.77899	-13.33333
66.66666	65.75343	62.6936	62.92974	59.41023	52.19751	-66.66666
65.51724	65.90909	64.55762	66.66666	61.27367	54.96354	-83.33334
200	73.91304	59.47712	61.90476	61.25461	59.10364	70.83334
200	122.5	64.88095	68.65174	60.86956	58.86274	52.38095
-100	69.38776	71.28205	67.55556	66.47565	60.36036	27.77778
107.1429	60.66666	56.08856	51.6	48.20513	41.24294	73.68421
163.6364	65.05376	61.78571	57.08502	49.39173	47.09302	83.87096
89.18919	68.01802	61.35135	60.42403	54.56475	50	75.75758

MAL(500 μ M)	MAL(1000 μ M)	MAL (250 μ M) + CP94 (250 μ M)	MAL (500 μ M) + CP94 (500 μ M)	MAL (1000 μ M) + CP94 (1000 μ M)	AP2-18 (250 μ M)	AP2-18 (500 μ M)	AP2-18 (1000 μ M)
45.94595	64.23529	67.03297	72.17281	67.97181	62.67039	58.36767	49.67301
38.80597	59.0389	62.95547	65.1497	63.96787	57.09666	52.30593	46.28474
42.64082	54.82063	55.63236	56.54206	55.94615	48.36871	42.8165	39.24669
56.25	46.66667	77.90697	82.48175	79.42583	59.53238	57.44681	61.74636
	300	61.79775	67.15328	68.83721	54.44265	57.77385	58.00416
300	116.6667	58.42697	73.8255	64.2534	56.63866	52.56765	54.76674
-75	209.6774	90.32258	85.13953	79.18216	47.49164	48.56828	44.37799
	167.8571	69.23077	72.95918	71.83099	47.4359	46.92388	45.3348
-171.4286	380	73.68421	68.29269	70.70064	45.45454	44.21699	43.99142

Table 4: PpIX photobleaching in human dermal fibroblasts (84BR) following irradiation - missing data is due to an infection present in these wells in this replicate and therefore data was discarded

Untreated	H2O2 (0.01%)	ALA (250 µM)	ALA (500 µM)	ALA (1000 µM)	ALA (250 µM) + CP94 (250 µM)	ALA (500 µM) + CP94 (500 µM)	ALA (1000 µM) + CP94 (1000 µM)
101.2462	104.6063	102.4162	100.2316	23.58852	102.195	72.97579	20.42218
100.1073	109.0359	100.3211	90.5351	15.83537	84.85323	19.46058	15.74945
98.64657	112.9591	98.90434	77.44377	15.98693	74.06719	16.07303	15.14433
104.4733	9.466929	108.0406	84.67118	52.72737	51.34414	14.40936	12.83199
92.99485	9.475019	110.2246	93.22134	24.20525	25.726	9.418395	10.93105
102.5319	10.47807	115.0942	91.31232	15.5661	15.46903	8.253566	10.21921
104.7793	13.74779	121.2573	150.8582	48.11189	76.61053	21.76957	16.72478
91.68053	12.79837	111.3528	127.6699	17.93166	26.58907	12.08228	12.12251
103.5402	14.5041	100.1126	31.14306	14.311	12.02596	11.14896	12.19493

MAL(250 µM)	MAL(500 µM)	MAL(1000 µM)	MAL (250 µM) + CP94 (250 µM)	MAL (500 µM) + CP94 (500 µM)	MAL (1000 µM) + CP94 (1000 µM)	AP2-18 (250 µM)	AP2-18 (500 µM)	AP2-18 (1000 µM)
89.28648	80.92455	97.25169	105.9153	83.20242	16.72019	15.28893	16.63427	15.33811
85.813	97.40708	109.2407	98.83304	78.8296	19.45144	16.318	16.76407	15.13338
96.99026	87.44188	101.8751	111.4728	102.5935	79.80573	15.48254	15.41673	18.64888
109.2883	95.90692	97.31442	96.00399	18.29212	12.19295	14.29611	11.1171	10.50233
100.3397	89.15253	107.9354	88.64292	23.6471	11.0443	9.119099	9.555909	9.475019
100.8655	85.86836	105.4763	82.96438	46.13477	10.39717	9.71769	8.010893	7.824844
108.4321	100.1609	98.04485	111.7068	22.2845	13.51446	13.07998	13.2246	12.55699
121.8447	86.03229	101.4322	132.4733	25.06034	13.434	14.02135	13.08802	13.20067
107.4264	93.77246	103.8781	133.9538	37.99013	14.02135	15.34088	15.46618	12.88887

Table 5: human dermal fibroblasts (84BR) cell viability following irradiation

ALA (250 μ M)	ALA (500 μ M)	ALA (1000 μ M)	ALA (250 μ M) + CP94 (250 μ M)	ALA (500 μ M) + CP94 (500 μ M)	ALA (1000 μ M) + CP94 (1000 μ M)	MAL(250 μ M)
68.34532	71.24183	98.34711	63.38028	60.22727	58.84058	-52.94118
78.37838	77.12418	100.7194	60	63	56.33075	-112.5
86.92308	83.33334	100.6897	67.20779	67.64706	58.99705	187.5
71.42857	88.88889	42.3913	76.47059	66.66666	61.34752	81.05264
387.5	101.4493	66.34615	74.83443	72.36842	63.57388	100
77.27273	93.58974	115.3846	70.19231	72.36842	59.52381	92.77109
1300	583.3333	61.68224	60.56338	55.86855	62.06897	
123.0769	60.31746	75	71.42857	54.07407	59.82659	
100	69.84127	51.72414	63.80368	56.49123	53.30296	

MAL(500 μ M)	MAL(1000 μ M)	MAL (250 μ M) + CP94 (250 μ M)	MAL (500 μ M) + CP94 (500 μ M)	MAL (1000 μ M) + CP94 (1000 μ M)	AP2-18 (250 μ M)	AP2-18 (500 μ M)	AP2-18 (1000 μ M)
-216.6667	72.22222	48	42.96296	76.72414	71.23746	67.94118	70.70064
-183.3333	52.99145	58.06452	58.66667	70.75813	72.34727	73.35767	69.68839
-33.33333	45.51282	66.66666	65.89147	68.92857	68.21918	68.26347	66.26665
-212.5	40.25974	68.60465	67.40741	77.61194	72.69231	74.51737	75.68627
-400	-209.0909	85	72.32704	63.87096	72.37354	68.67088	67.60125
-250	-110.7143	89.53488	80.24691	53.68421	67.63636	64.47369	72.35773
	24.63768			47.24638	65.61404	62.43386	57.71812
	17.70833			73.05936	60.13746	65.86021	66.96429
	144.4444			74.39613	66.31206	62.72906	57.23684

Table 6: PpIX photobleaching in human epithelial squamous cell carcinoma cells (A431) following irradiation - missing data is due to an infection present in these wells in this replicate and therefore data was discarded

Untreated	H2O2 (0.01%)	ALA (250 μ M)	ALA (500 μ M)	ALA (1000 μ M)	ALA (250 μ M) + CP94 (250 μ M)	ALA (500 μ M) + CP94 (500 μ M)	ALA (1000 μ M) + CP94 (1000 μ M)
96.65799	4.849673	82.00058	67.68867	59.29512	13.57674	14.4515	7.172801
103.6911	5.759535	64.97372	28.72551	27.29197	5.364579	5.806345	7.371542
99.65088	4.993027	20.13594	8.056132	6.353432	5.812196	5.215373	8.129272
104.3352	5.718442	125.0307	111.2275	109.5082	42.7303	35.39415	8.76577
92.51461	4.676331	150.1618	105.7573	86.84508	19.92049	11.32778	8.318076
103.1502	4.089438	127.1037	29.3785	18.6677	7.212009	8.348173	9.096837
80.40414	12.24248	6.313455	108.0828	42.58255	36.20996	32.91277	26.64367
65.16018	13.02612	9.566289	59.77822	43.46969	30.36443	36.18039	30.56185
154.4357	18.54115	15.90932	39.69936	28.34401	32.23263	32.12913	26.14096

MAL (250 μ M)	MAL (500 μ M)	MAL (1000 μ M)	MAL (250 μ M) + CP94 (250 μ M)	MAL (500 μ M) + CP94 (500 μ M)	MAL (1000 μ M) + CP94 (1000 μ M)	AP2-18 (250 μ M)	AP2-18 (500 μ M)	AP2-18 (1000 μ M)
109.5656	90.23762	91.78101	84.56491	78.0531	5.721502	7.087759	6.022839	6.315399
90.46208	110.2301	85.804	93.39406	86.45865	5.949699	6.581629	6.335878	6.00236
107.8629	98.69321	110.3323	95.46222	87.3723	5.455272	5.92922	6.645992	5.891187
109.4385	113.2846	138.7081	93.81889	115.7124	5.778636	7.339921	7.159339	7.607033
93.63615	104.0869	132.5587	98.55282	103.9825	7.023902	6.990043	7.629605	8.758245
106.3887	74.42279	155.8802	118.7493	103.9999	8.3256	6.519776	6.692834	7.382494
		165.2883			33.6964	32.02563	42.87827	38.06773
		91.72992			33.74076	32.79448	32.5727	34.19911
		106.1163			27.57516	31.10892	25.10596	25.29818

Table 7: human epithelial squamous cell carcinoma cells (A431) cell viability following irradiation - missing data is due to an infection present in these wells in this replicate and therefore data was discarded

ALA (250 μ M)	ALA (500 μ M)	ALA (1000 μ M)	ALA (250 μ M) + CP94 (250 μ M)	ALA (500 μ M) + CP94 (500 μ M)	ALA (1000 μ M) + CP94 (1000 μ M)	MAL(250 μ M)
40.90452	41.88931	44.39164	39.88439	32.35639	41.33226	107.6923
48.36717	44.51561	46.24574	43.04462	38.65883	42.78642	-220
48.02933	46.74267	47.24733	46.95432	38.89717	44.4619	200
51.39319	48.48485	47.14286	51.61871	48.80548	40.42715	83.49515
58.07365	51.81024	48.47909	53.81818	50.625	38.49028	86.40777
51.31004	53.53535	49.48742	55.44933	52.01342	37.32336	82.47423
35.71429	56.53595	52.17391	55.60166	46.44195	49.12043	
47.82609	54.02299	55.2	65.24064	52.26337	47.18217	
160	53.9548	55.82609	59.84556	51.51515	45.81993	

MAL(500 μ M)	MAL(1000 μ M)	MAL (250 μ M) + CP94 (250 μ M)	MAL (500 μ M) + CP94 (500 μ M)	MAL (1000 μ M) + CP94 (1000 μ M)	AP2-18 (250 μ M)	AP2-18 (500 μ M)	AP2-18 (1000 μ M)
-300	51.95823	52.43903	59.74026	55.04056	46.44444	44.79452	42.67241
0	47.66133	58.22765	57.89474	52.07226	45.11111	43.0593	41.29032
0	46.84579	63.73626	55.80111	50.3006	45.47368	41.8983	41.50943
133.3333	64.26735	72.34042	66.5	53.6036	51.3369	47.68392	49.03181
118.5185	60.25317	80	76.37363	53.57143	49.8954	47.31707	47.21635
89.74359	57.65306	66.98113	70.38635	48.66071	47.11014	43.60746	42.07534
	63.88889			59.95204	53.73406	53.25814	49.05063
	54.76191			55.78704	52.04991	50.39282	49.34641
	49.68554			57.08061	48.93268	49.36999	47.38676

Table 8: PpIX photobleaching in human glioblastoma cells (U87MG) following irradiation - missing data is due to an infection present in these wells in this replicate and therefore data was discarded

Untreated	H2O2 (0.01%)	ALA (250 μ M)	ALA (500 μ M)	ALA (1000 μ M)	ALA (250 μ M) + CP94 (250 μ M)	ALA (500 μ M) + CP94 (500 μ M)	ALA (1000 μ M) + CP94 (1000 μ M)
94.14043	2.062079	2.360817	2.474841	3.147201	3.38084	2.295717	1.964729
106.7374	1.960835	1.71811	2.548826	2.012755	1.934875	2.489119	1.784308
99.12212	2.282737	2.596852	2.951204	2.583872	2.481331	2.557912	2.277546
90.18543	1.812221	34.20962	2.057359	2.260388	6.414209	2.857444	1.854331
102.0784	2.215271	6.522491	1.809213	1.848315	2.338592	1.475343	2.185842
107.7362	1.56257	4.05757	1.765599	2.174865	2.078414	1.721986	1.705443
190.5858	23.02261	22.80774	26.52205	25.96951	31.15727	25.23278	23.20679
60.7797	21.33429	18.63297	36.00737	29.56104	37.94127	20.04502	24.98721
48.65446	23.57516	21.48777	27.22808	32.69211	32.90699	14.21263	24.097

MAL(250 μ M)	MAL(500 μ M)	MAL(1000 μ M)	MAL (250 μ M) + CP94 (250 μ M)	MAL (500 μ M) + CP94 (500 μ M)	MAL (1000 μ M) + CP94 (1000 μ M)	AP2-18 (250 μ M)	AP2-18 (500 μ M)	AP2-18 (1000 μ M)
101.9185	81.62376	2.524164	29.45828	20.62864	2.172408	3.188737	2.369703	2.589064
89.24873	83.80233	2.394365	27.85205	18.05314	2.509886	2.865536	3.016104	2.554018
101.7108	72.46181	3.03168	48.08683	27.24741	2.26197	2.446285	3.171863	2.373597
38.90113	73.95813	3.553757	29.13108	6.831562	1.726498	1.828764	2.064879	2.4183
42.22094	78.24413	4.85615	46.93977	8.16876	1.969663	1.718976	2.875491	1.795678
53.14267	80.89823	16.7356	21.84219	5.285668	2.673966	1.660325	2.078414	12.01029
		27.74992			24.74163	31.61772	37.17385	22.71564
		26.52205			26.82902	25.01791	36.95897	25.87742
		29.31546			25.29418	17.71206	21.08871	17.61997

Table 9: human glioblastoma cells (U87MG) cell viability following irradiation - missing data is due to an infection present in these wells in this replicate and therefore data was discarded

Substantial PpIX photobleaching (i.e. a reduction in PpIX fluorescence during light irradiation) was observed in the vast majority of the treatment groups investigated (see Figures 5A, 6A and 7A). This demonstrated that PpIX was being consumed during the light treatment and indicated that PDT was occurring within all three cell types investigated. Complete PpIX photobleaching was rarely achieved with the particular treatment parameters employed here however.

Analysis of the cell viability results (see Figures 5B and 5C, 6B and 6C, and 7B and 7C) revealed that both the blank control and hydrogen peroxide positive control groups were successful in all three cell types, producing little cytotoxicity and considerable cell death respectively. In human dermal fibroblasts (84BR; Figures 5B and 5C), the use of the iron chelator CP94 (**3**) improved the PDT effect of both ALA and MAL in a concentration dependent manner, but the novel compound AP2-18 (**8**) was found to be significantly better (than any of the other treatment parameters investigated) at reducing cell viability following PDT when the lowest concentration employed (250 μ M) was considered. At higher doses when significance was not achieved, the level of cell kill produced by AP2-18 (**8**) was equivalent to (or better than) that observed with the other treatment groups. Very similar trends and significant reductions in cell viability were also observed in the human epithelial squamous carcinoma cells (A431; Figures 6B and 6C). It can therefore be concluded in these particular cell types that AP2-18 (**8**) is an efficacious prodrug for PpIX-induced PDT which achieved this effect at lower concentrations than possible with ALA or MAL with or without administration of the iron chelator CP94 (**3**). Less significant improvements in cell kill over and above the other prodrugs administered with and without the iron chelator CP94 (**3**) were observed with AP2-18 (**8**) in the human glioblastoma cells (U87MG; Figures 7B and 7C) however, as these cells appear to be more susceptible to the cytotoxic effects of PpIX-PDT at lower doses. Despite this, AP2-18 (**8**) still produced highly effective PpIX-induced PDT cell kill in this cell type as well.

The significant increases in cytotoxicity observed for PpIX-induced PDT conducted with compound AP2-18 (**8**) could potentially be translated into clinical PDT settings to produce substantial benefits for patients undergoing dermatological PDT and other PDT applications.

2D. PDT Efficacy in human epithelial squamous carcinoma cells (A431) with variable incubation periods

Human epithelial squamous carcinoma cells (A431) were exposed to equimolar concentrations of ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**), and AP2-18 (**8**) (as described previously) and incubated in the dark for incubation periods of 2, 3 or 4 hours. The level of PpIX accumulation was then measured; the results are given in Table 10 below and are shown in Figure 8A (ALA, ALA and CP94 (**3**)), Figure 8B (MAL, MAL and CP94 (**3**)) and Figure 8C (CP94 (**3**)). Figure 9 compares the level of PpIX accumulation measured in human epithelial squamous cell carcinoma cells (A431) following exposure to ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**), and AP2-18 (**8**), after the cells had been incubated with the compound(s) for 2 hours (Figure 9A(i)), 3 hours (Figure 9B(i)) and 4 hours (Figure 9C(i)). The results of corresponding statistical analyses for each incubation period are presented in Figure 9A(ii) (2 hours), Figure 9B(ii) (3 hours), and Figure 9C(ii) (4 hours).

After the relevant incubation period, the cells were irradiated with red light (37 J/cm^2 ; $635 \pm 2 \text{ nm}$; Aktelite, Galderma, UK). Cell viability was then assessed using the NRU assay (as described previously); the results of the cell viability tests are given in Table 11 below. These data were normalised against the blank control cells (which were exposed to normal cell media) and presented as a percentage of viable cells in Figures 10A (ALA, ALA and CP94 (**3**)), 10B (MAL, MAL and CP94 (**3**)), and 10C (AP2-18 (**8**)). Figure 11 compares the percentage of viable cells following exposure to ALA, ALA and CP94 (**3**), MAL, MAL and CP94 (**3**), and AP2-18 (**8**), after the cells had been incubated with the compound(s) for 2 hours (Figure 11A(i)), 3 hours (Figure 11B(i)) and 4 hours (Figure 11C(i)). The results of corresponding statistical analyses for each incubation period are presented in Figure 11A(ii) (2 hours), Figure 11B(ii) (3 hours), and Figure 11C(ii) (4 hours).

Incubation time:	Drug								
	ALA (250 μ M)			ALA (500 μ M)			ALA (1000 μ M)		
	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours
	-1.33	3	13.33	-3.67	7	22.67	1.33	14.33	32.33
	1.67	8	17.33	-1.67	9	25.67	9.33	25.33	45.33
	3.67	8	17.33	-2.67	6	27.67	14.33	26.33	43.33
	10	18	28	15.33	27	38	12.33	27.33	38.33
	9	19	28	12.33	24	36	15.33	28.33	38.33
	11	18	28	19.33	32	43	16.33	32.33	45.33
	-1	-0.66667	-0.33333	3.66667	2.66667	5	8.33333	12.33333	12.33333
	-1	0.33333	-0.33333	0.66667	2.66667	4	6.33333	10.33333	12.33333
	1.33333	-0.66667	1.33333	5	4.66667	6.66667	9.66667	9.33333	12

Incubation time:	Drug								
	ALA (250 μ M) + CP94 (250 μ M)			ALA (500 μ M) + CP94 (500 μ M)			ALA (1000 μ M) + CP94 (1000 μ M)		
	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours
	26.67	46	70.67	38.67	69.33	108	4	15.67	35
	24.67	46	71.67	33.67	61.33	95	4	17.67	34
	19.67	38	61.67	37.67	69.33	102	5	15.67	38
	37	62	87.33	38	68	95	45	76.67	103.67
	34	58	77.33	44	73	100	46	77.67	100.67
	39	67	89.33	40	71	94	50	81.67	110.67
	18	23.33333	25	28.33333	33.66667	39	22	27	37
	16	19.33333	25	23.33333	30.66667	37	22	33	42
	15.33333	17.33333	20.66667	18.66667	21.66667	25.66667	22.33333	29	34.66667

Incubation time:	Drug								
	MAL (250 μ M)			MAL (500 μ M)			MAL (1000 μ M)		
	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours
	-5	-4.67	-4.67	-7.33	-3.67	-4.33	28	45	70
	1	-0.67	-2.67	4.67	-6.67	-7.33	21	50	74
	-0.33	1.33	-2.67	-5.67	5.33	3.67	9.67	42	64
	-5.33	0.67	-2.67	-5.67	-2.67	0.67	10.67	22.67	34.33
	-6.33	-3.33	-3.67	-7.67	0.33	3.67	11.67	25.67	39.33
	-11	-7.33	-8.67	8.67	-2.67	1.67	-3.66667	20.67	30.33
	-10	-11.67	-11.67	-2.33	7.67	9	0.33333	-3.33333	-2
	-16	-9.67	-10.67	1.67	-2.33	0	-8.33333	0.66667	4
	-4.33	-14.67	-15.67	21	1.67	2	51	-10.3333	-8.33333

Incubation time:	Drug								
	MAL (250 μ M) + CP94 (250 μ M)			MAL (500 μ M) + CP94 (500 μ M)			MAL (1000 μ M) + CP94 (1000 μ M)		
	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours
	42	51	65.67	54	57	73.67	40.33	34.33	51.33
	50	42	53.67	61	54	72.67	40.33	40.33	61.33
	28	50	61.67	54.33	61	79.67	82.67	40.33	60.33
	24	28	35.67	40.33	54.33	68.33	74.67	82.67	110.67
	31	24	34.67	19.33	40.33	55.33	63.67	74.67	96.67
	21.33	31	39.67	26	19.33	27.33	9.666667	63.67	86.67
	30.33	21.33	27.33	27	26	39.33	11.66667	9.666667	11.33333
	19.33	30.33	37.33	24	27	36.33	3.666667	11.66667	10.33333
	57	19.33	26.33	34.33	24	33.33	20.33	3.666667	5

Incubation time:	Drug								
	AP2-18 (250 μ M)			AP2-18 (500 μ M)			AP2-18 (1000 μ M)		
	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours
	17.33	42.33	53.67	35.33	59.33	71.67	58.33	96.33	113.67
	19.33	42.33	52.67	33.33	67.33	82.67	69.33	100.33	119.67
	43.67	46.33	57.67	57.67	62.33	73.67	58.67	116.33	140.67
	42.67	100.33	127.67	49.67	114.33	137.67	58.67	117.33	145.67
	41.67	96.33	120.67	55.67	109.33	136.67	63.67	114.33	139.67
	44.67	97.33	120.67	58.67	114.33	140.67	78.67	118.33	141.67
	54.67	89.67	113.67	69.67	119.67	151.67	97.67	144.67	177.67
	48.67	111.67	144.67	58.67	139.67	177.67	93.67	180.67	221.67
	34.33	111.67	141.67	58.33	118.67	146.67	93.67	182.67	225.67

Table 10: PpIX fluorescence measured in human epithelial squamous cell carcinoma cells (A431) after varying incubation periods

Incubation time:	Drug								
	ALA (250 μ M)			ALA (500 μ M)			ALA (1000 μ M)		
	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours
	104.2825	124.0654	82.00658	99.83801	118.05	67.68867	87.30403	146.327	59.29512
	103.9063	135.6267	64.97372	113.3557	77.38437	28.72551	106.5283	79.28516	27.29197
	123.5695	95.30766	20.13594	112.7404	69.99367	8.056132	118.4391	120.4428	6.353432
	112.4377	55.77225	125.0307	95.2285	77.17889	111.2275	110.6882	43.81615	109.5082
	117.6227	55.32471	150.1618	69.93956	78.53456	105.7573	113.0739	38.84751	86.84508
	97.70968	62.01816	127.1037	82.25002	70.10976	29.3785	122.8714	34.80008	18.6677
	44.14486	56.04799	6.313455	65.55643	42.15261	108.0828	119.6405	39.78674	42.58255
	34.7079	85.67144	9.566289	62.54295	44.3852	59.77822	111.0759	27.42419	43.46969
	50.72694	55.08164	15.90932	64.52551	60.84639	39.69936	80.14803	54.74842	28.34401
		120.1384			274.4678			57.2548	
		57.17644			51.10357			73.63197	
		77.31487			55.09991			60.03657	

Incubation time:	Drug								
	ALA (250 μ M) + CP94 (250 μ M)			ALA (500 μ M) + CP94 (500 μ M)			ALA (1000 μ M) + CP94 (1000 μ M)		
	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours
	80.84892	118.2625	13.57674	62.6829	179.602	14.4515	88.87176	187.2722	7.172601
	94.75857	105.4936	5.364579	58.74007	194.7971	5.806345	83.52973	187.8648	7.371542
	89.78888	107.0143	5.812196	74.94252	178.8193	5.215373	54.14272	188.6922	8.129272
	65.13625	79.84451	42.7303	80.40504	156.1218	35.39415	133.3051	159.1827	8.76577
	64.84996	81.08912	19.92049	101.4314	169.8354	11.32778	164.7651	150.049	8.318076
	96.65995	72.26578	7.212009	91.4113	152.0678	8.348173	135.2773	146.1486	9.096837
	86.5715	39.38687	36.20996	114.9617	60.24659	32.91277	68.80782	78.64045	26.64367
	105.5247	20.22659	30.38443	130.7428	63.47884	36.18039	78.08617	109.7634	30.56185
	58.41924	30.35655	32.23263	49.85461	55.64812	32.12913	105.3661	78.87371	26.14096
		52.82748			130.1685			257.5813	
		37.6257			120.4127			178.438	
		49.26211			154.1857			208.3714	

Incubation time:	Drug								
	MAL (250 μ M)			MAL (500 μ M)			MAL (1000 μ M)		
	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours
	78.62667	92.90373	109.5656	103.8357	40.77746	90.23782	113.344	93.27271	91.78101
	100.9237	73.67224	90.46208	110.62	47.70974	110.2301	113.9162	84.83098	85.804
	89.57724	65.45414	107.8629	117.5455	49.73352	98.69321	113.1911	88.71082	110.3323
	117.6227	62.6519	109.4385	82.91804	71.70718	113.2846	108.366	39.35058	138.7061
	107.2209	51.74115	93.63615	108.8432	76.88815	104.0869	113.6783	38.50124	132.5587
	106.7755	54.37083	106.3667	82.88622	81.86658	74.42279	85.84456	43.00928	155.8802
	45.7309	33.35555	111.1665	99.49775	74.40853	104.4856	45.88951	59.91336	165.2883
	63.25668	40.45318	115.1445	114.8824	55.24825	97.35677	39.14882	53.88204	91.72992
	57.86413	63.31223	124.4547	75.70711	104.0986	135.6405	53.81972	52.9157	106.1163
		38.2134			49.37965			75.55178	
		54.70811			75.04244			92.94763	
		47.85164			67.40237			90.51848	

Incubation time:	Drug								
	MAL (250 μ M) + CP94 (250 μ M)			MAL (500 μ M) + CP94 (500 μ M)			MAL (1000 μ M) + CP94 (1000 μ M)		
	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours
	86.58288	80.44799	84.56491	83.34945	156.0993	78.0531	83.34945	167.2245	5.721502
	72.87312	79.66531	93.39406	49.87458	170.7465	86.45865	49.87458	183.0345	5.949699
	99.5323	74.53319	95.46222	52.11251	178.2043	87.3723	52.11251	162.685	5.455272
	116.0004	40.28812	93.81889	92.87457	47.54998	115.7124	92.87457	69.35842	5.778636
	67.87191	40.98719	98.55262	142.53	52.36509	103.9825	142.53	82.5134	7.023902
	90.32977	40.64093	118.7493	127.0067	32.83026	103.9999	127.0067	158.9965	8.3256
	60.4811	55.6148	102.8575	107.9831	53.08231	124.7128	107.9831	76.27457	33.6964
	57.38832	64.94501	92.07208	94.10521	63.21226	130.2821	94.10521	107.4309	33.74076
	95.29474	50.08331	127.9532	133.4391	81.17294	114.8864	133.4391	71.57614	27.57516
		55.68761			75.35588			202.8471	
		61.64294			83.07431			156.5757	
		58.07758			74.25885			170.8763	

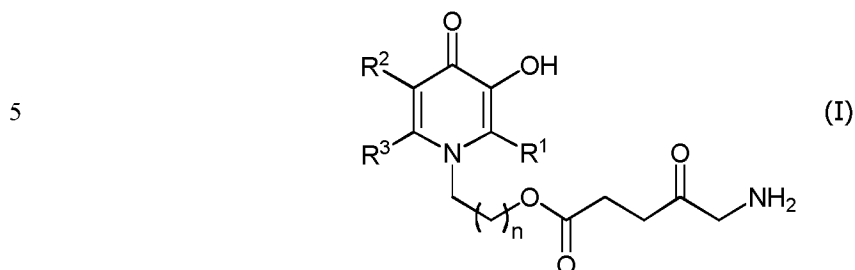
Incubation time:	Drug								
	AP2-18 (250 μ M)			AP2-18 (500 μ M)			AP2-18 (1000 μ M)		
	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours	2 hours	3 hours	4 hours
	97.70197	86.93302	7.087759	12.85666	102.5418	6.022839	96.31454	92.46767	6.315399
	86.78668	101.2448	6.581629	12.73516	125.9215	6.335878	83.65123	93.28389	6.00236
	91.72502	79.69885	5.92922	16.03522	67.09776	6.645992	82.62045	87.84988	5.891187
	133.2414	62.45917	7.339921	53.68466	33.03933	7.159339	98.18683	39.73278	7.607033
	62.65508	60.17248	6.990043	42.01039	31.45498	7.629605	107.1891	38.73971	8.758245
	106.5847	62.3481	6.519776	55.46601	38.58617	6.692834	53.90733	37.67804	7.362494
	64.28761	33.55548	32.02563	60.63971	68.87704	42.87827	80.38594	45.15162	38.08773
	96.80148	37.88737	32.79448	70.31457	42.18594	32.5727	46.20671	47.25092	34.19911
	131.2186	49.01699	31.10892	124.24	58.38054	25.10596	97.83241	41.05298	25.29818
		32.64986			49.61473			50.59423	
		47.7341			46.3628			59.84067	
		52.74912			69.55727			82.36907	

Table 11: cell viability of human epithelial squamous cell carcinoma cells (A431) after varying incubation periods – an extra viability experiment (of three more replicates) was conducted for the 3 hour time point resulting in more data at this time point than at 2 hours or 4 hours.

Figures 8 and 9 indicate a time dependent increase in PpIX levels with all three PpIX-prodrugs investigated. It is clear that although the addition of the iron chelator CP94 (**3**) to the ALA or MAL incubation period improved PpIX levels, this was outperformed by the combinational iron chelating PpIX-prodrug AP2-18 (**8**) (with four hours incubation of 1000 μ M AP2-18 (**8**) in A431 human squamous epithelial carcinoma cells producing statistically significant higher PpIX levels than any other treatment parameters investigated). It should also be noted that the lowest dose of AP2-18 (**8**) (250 μ M) at the shortest incubation time (2 hours) investigated also produced more PpIX than the highest doses of ALA or MAL (1000 μ M) employed at the longest incubation time (4 hours). Importantly the increased PpIX accumulation observed with AP2-18 (**8**) was also translated on irradiation (Figures 10 and 11) into statistically significant increases in cell kill (when compared with that produced by either ALA or MAL) with the greatest cytotoxicity being produced at 4 hours.

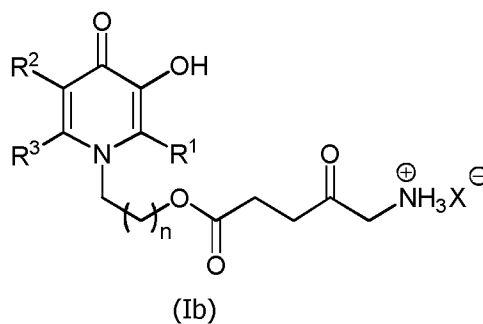
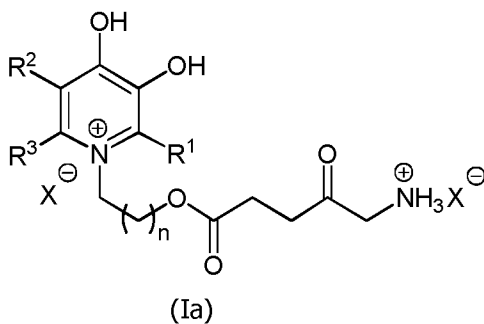
Claims

1. A compound which is a compound of formula (I) or any salt thereof:



wherein

- 10 R^1 is a C_1 - C_6 alkyl group,
 R^2 is H or a C_1 - C_6 alkyl group,
 R^3 is H or a C_1 - C_6 alkyl group, and
 n is an integer from 0 to 5.
- 15 2. The compound according to claim 1, which is a compound of formula (I) as defined in claim 1, a salt of formula (Ia) or a salt of formula (Ib):



wherein

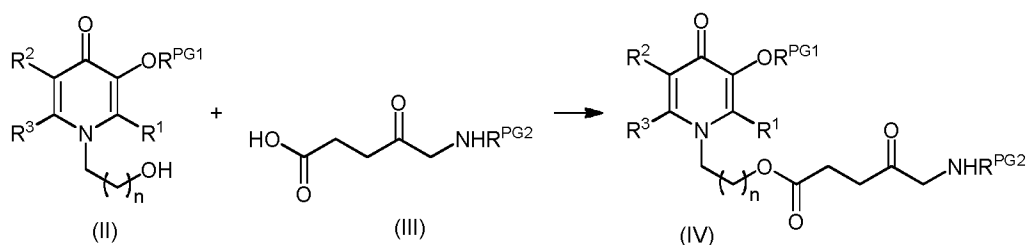
- 20 R^1 , R^2 , R^3 and n are as defined in claim 1; and
each X^- is independently selected from monovalent counterions.
3. The compound according to claim 2, wherein X^- is Cl^- .
- 25 4. The compound according any one of the preceding claims, wherein R^1 is ethyl, R^2 and R^3 are H, and n is 1.

5. A pharmaceutical composition comprising a compound according to any one of claims 1-4 and a pharmaceutically acceptable carrier.

6. A process for making a compound according to any one of claims 1-4, the method comprising the step of:

(a) reacting a compound of formula (II) with a compound of formula (III) via an esterification reaction to form a compound of formula (IV);

10 in accordance with the following reaction scheme:

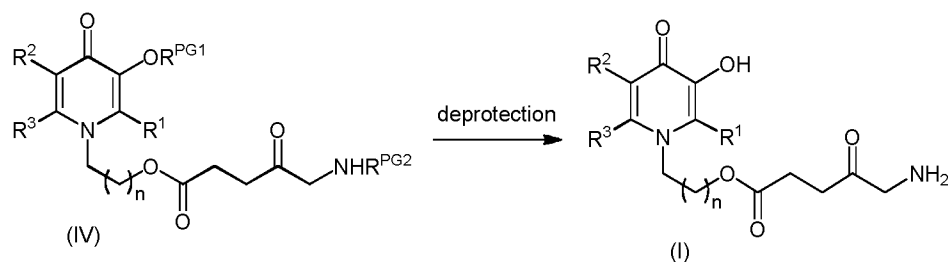


wherein R^1 , R^2 , R^3 and n are as defined in claim 1; and R^{PG1} and R^{PG2} are protecting groups.

7. The process according to claim 6, further comprising the step of:

(b1) deprotecting the compound of formula (IV) to give a compound of formula (I);

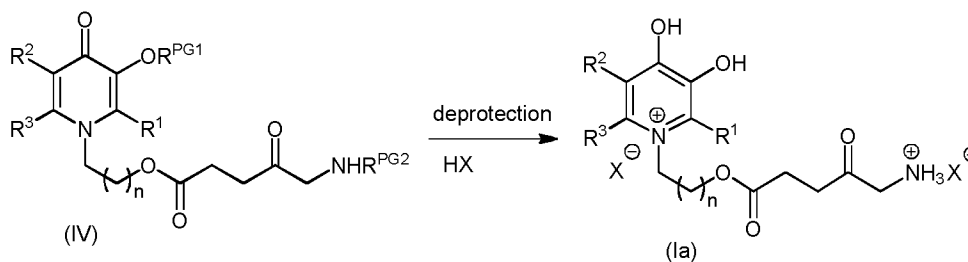
20 in accordance with the following reaction scheme:



8. The process according to claim 6, further comprising the step of:

(b2) deprotecting the compound of formula (IV) in the presence of acid H^+X^- to give a salt of formula (Ia);

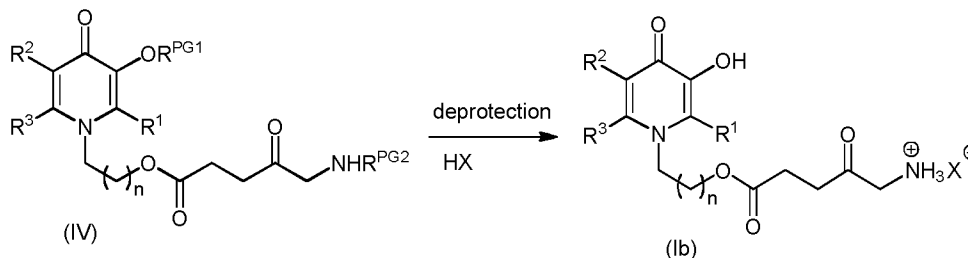
5 in accordance with the following reaction scheme:



9. The process according to claim 6, further comprising the step of:

10 (b3) deprotecting the compound of formula (IV) in the presence of acid H^+X^- to give a salt of formula (Ib);

in accordance with the following reaction scheme:



15

10. A compound according to any one of claims 1-4 for use in therapy.

11. A compound according to any one of claims 1-4 for use in photodynamic therapy.

20 12. The compound for use according to claim 11, wherein the compound is for use in treating a condition, which is caused by and/or exacerbated by the abnormal proliferation of cells, by photodynamic therapy.

13. The compound for use according to claim 11, wherein the compound is for use in
25 treating cancer, by photodynamic therapy.

14. The compound for use according to claim 11, wherein the compound is for use in treating scleroderma, lichen sclerosus, psoriasis, warts, chronic wounds, acne, a microbial infection, a parasitic infestation, or rheumatoid arthritis, by photodynamic therapy; or the
5 compound is for use in bone marrow purging, by photodynamic therapy, in the treatment of leukaemia.
15. Use of a compound according to any one of claims 1-4 in photodynamic treatment for cosmetic purposes.
- 10 16. A compound according to any one of claims 1-4 for use in a diagnostic method practised on the human or animal body.
17. The compound for use according to claim 16, wherein the diagnostic method is a
15 method of diagnosing a condition which is caused by and/or exacerbated by the abnormal proliferation of cells.
18. Use of a compound according to any one of claims 1-4 in an *in vitro* diagnostic method.
- 20 19. Use of a compound according to any one of claims 1-4 in the manufacture of a medicament for the treatment, by photodynamic therapy, of a condition which is caused by and/or exacerbated by the abnormal proliferation of cells.
- 25 20. A method of treatment of a human or animal patient suffering from or at risk of suffering from a condition which is caused by and/or exacerbated by the abnormal proliferation of cells, the method involving administering to the patient a therapeutically effective amount of a compound according to any one of claims 1-4, and exposing a region of the patient containing the compound to light as part of a photodynamic therapy.
- 30