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Concise Preparation of 1,8-Diazaanthracene-2,7,9,10-Tetraones. Two Alternative Syntheses of the Natural Antifolate Diazaquinomycin A

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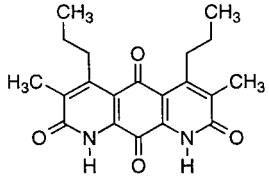
Abstract—Treatment of compounds bearing one or two 1-dimethylamino-1,4-dihydropyridine moieties with the urea-hydrogen peroxide complex (UHP) led to their efficient aromatization. Double *N*-oxidation of 1,8-diazaanthraquinones thus obtained is the first example of a double *N*-oxidation of a diaza heterocycle by UHP in trifluoroacetic acid. Treatment of the crude double *N*-oxides with tosyl chloride in acetonitrile–water afforded 1,8-diazaanthracene-2,7,9,10-tetraones (including diazaquinomycin A) in 25–40% overall yields. An alternative synthesis of diazaquinomycin A was also devised, whose key steps are the hetero Diels–Alder reaction between 2-methyl-2-hexenal dimethylhydrazone and 3-methyl-4-propyl-2*H*-quinoline-2,5,8-trione and the oxidative functionalization of the 1,8-diazaanthracene-2,9,10-trione derivative thus obtained.

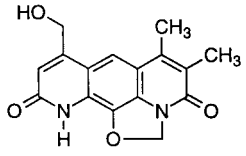
Introduction

As part of an effort to study the biological activity of bacterial secondary metabolites, Omura's group[1] described the isolation from a *Streptomyces* strain of a compound with antibacterial properties, which they named diazaquinomycin A. Further research from the same group[2] allowed them to attribute the antibiotic activity to inhibition of thimidylate synthase. This finding made diazaquinomycin A an attractive lead compound in the field of cancer chemotherapy, although the natural product itself lacked antitumour activity because of its poor pharmacokinetic properties.[3] Diazaquinomycin A is also interesting because its 1,8-diazaanthracene-2,7,9,10-tetraone structure is unique, although related natural products, like nibomycin A,[4] are known. The only prior total synthesis of diazaquinomycin A was that by Kelly and coworkers, and featured a double Knorr cyclization as the key step.[5]

The rearrangement of pyridine and quinoline *N*-oxides to the corresponding unsaturated δ-lactams is a well-known transformation.[6] Therefore, we envisaged that a double rearrangement of double *N*-oxides derived from 1,8-diazaanthraquinones would provide an efficient entry into symmetrically substituted 1,8-diazaanthracene-2,7,9,10-tetraones. Alternatively, these compounds could also be prepared by *N*-oxidation and rearrangement of the products obtained in the hetero Diels–Alder reaction[7] between 1-dimethylamino-1-azadienes and 2,5,8(1*H*)-quinolinetriones (Scheme 1).



Diazaquinomycin A (1)



Nibomycin A

Results and Discussion

N-oxidation of nitrogen atoms that are deactivated by the presence of electron-withdrawing groups requires the use of very strong oxidants. For instance, the preparation of *N*-oxides of polyhalogenated pyridines and pyrazines

Keywords: *N*-oxides; rearrangements; lactams; quinones; Diels–Alder reactions.

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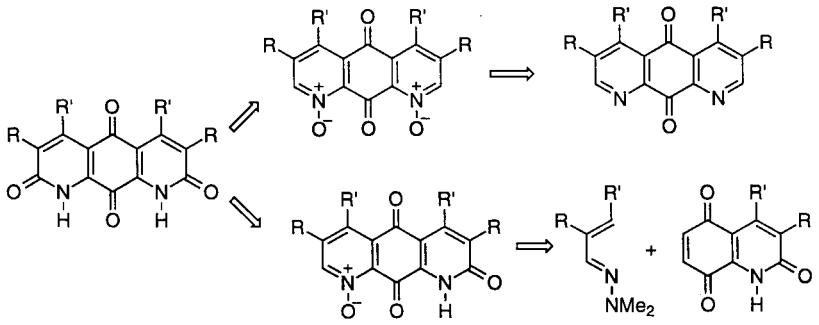
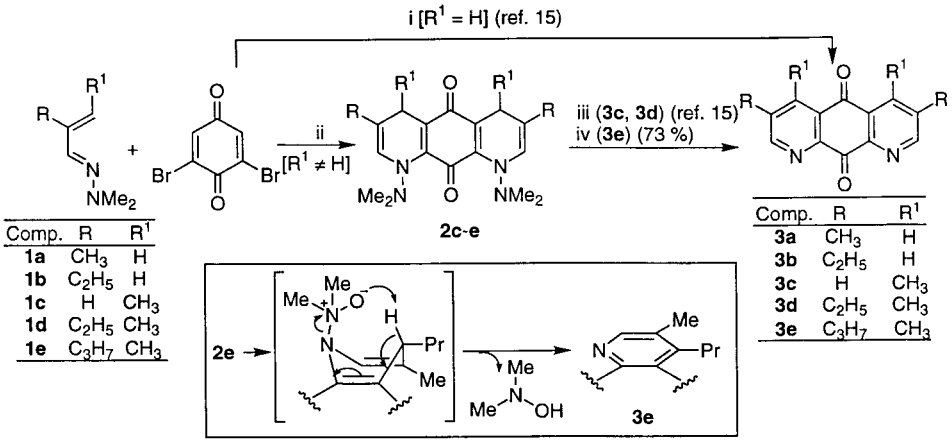


Scheme 1.

required the use of 90% hydrogen peroxide in acidic media.[8] In order to avoid the dangers inherent to this reagent, a number of alternatives have been proposed, like peroxyimidic acid,[9] magnesium monoperoxyphthalate,[10] and several compounds where hydrogen peroxide is hydrogen-bonded to a variety of molecules containing electron donors. Among these, hydrogen peroxide–urea adduct (UHP, percarbamide)[11] is the most widely used and has been successfully employed on very deactivated substrates, including heterocyclic quinones;[12] recent advances in the use of UHP include the development of a solid-state protocol suitable for liquid or low-melting substrates.[13] However, double *N*-oxidations using this reagent are unknown; for instance, an attempt to use UHP to transform quinoxaline into its double *N*-oxide was unsuccessful, while magnesium monoperoxyphthalate gave a 72% yield of the desired product.[14]

The 1,8-diazaanthraquinones **3a–d** used as starting materials for our study were prepared through literature methods,[15] by double hetero Diels–Alder reactions of 1-dimethylamino-1-azadienes and 2,6-dibromobenzoquinone[16] followed by aromatization under thermal conditions. However, 3,6-dimethyl-4,5-dipropyl-1,8-diazaanthraquinone **3e**, the starting material required for the preparation of diazaquinomycin itself, was not available by this route because of failure of the aromatization step, probably due to the steric compression between the C_4- and C_5-alkyl groups and the C_{10} carbonyl in the desired product. Fortunately, we discovered that brief exposure of the bis(dimethylamino) intermediate **2e** to UHP in trifluoroacetic acid at room temperature afforded compound **3e** in 73% overall yield. This aromatization can be explained through the *N*-oxidation of the dimethylamino group of compound **2e** followed by an aza-Cope elimination (Scheme 2); the *N*-oxidation step is probably very fast, which prevents decomposition of the acid-sensitive starting material under the conditions employed. In fact, addition of neat trifluoroacetic acid to **2e** in the absence of UHP led to its rapid decomposition. This aromatization of **2e** was of interest to us because of the mildness of the reaction conditions and the good yield obtained, and could be extended to other examples, as shown in Table 1 for the preparation of **3c**,**d** from **2c**,**d**, and also for the transformation of compound **4**[17] into the natural product cleistopholine **5**.[17,18] On the other hand, several attempts to aromatize 8-chloro-1-dimethylamino-4-methyl-1,4-dihydro-1,5-diazaanthracene-9,10-dione[19] by this method led to intractable mixtures, probably as a consequence of the sensitivity of the 4-chloropyridine subunit to trifluoroacetic acid.

Owing to the above mentioned lack of precedent on double *N*-oxidations with UHP, in our first experiments we attempted to oxidize 3,6-dimethyl-1,8-diazaanthraquinone with magnesium monoperoxyphthalate under several literature conditions,[20] but these reactions afforded only recovered starting material, even after very prolonged treatments. Use of UHP under standard conditions (reaction at room temperature in trifluoroacetic acid, followed by basification with ammonium hydroxide and extraction) was also

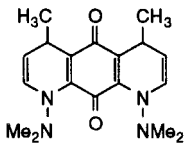
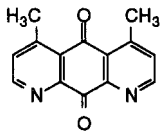
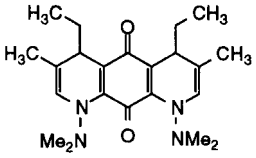
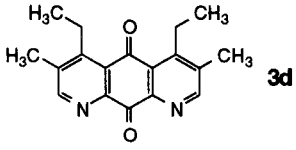
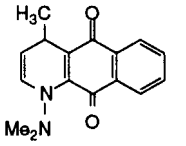
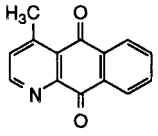


Comp.	R	R1
1a	CH_3	H
1b	C_2H_5	H
1c	H	CH_3
1d	C_2H_5	CH_3
1e	C_3H_7	CH_3

Comp.	R	R1
3a	CH_3	H
3b	C_2H_5	H
3c	H	CH_3
3d	C_2H_5	CH_3
3e	C_3H_7	CH_3

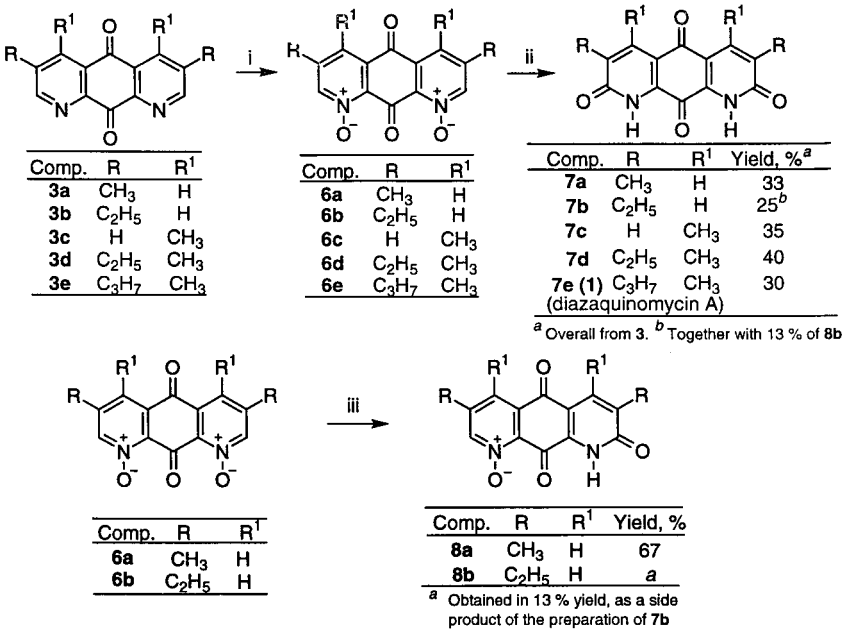
Scheme 2. Reagents and conditions: i. R.t., 5 min (ref. 15). ii. R.t., Et_3N, 15 min (ref. 15). iii. 110°C, 0.1 Torr, 2 h (ref. 15). iv. H_2O_2-urea, F_3C-CO_2H, r.t., 10 min.

Table 1. Aromatization of 1-dimethylamino-1,4-dihydropyridine rings in the presence of UHP (TFA, rt, 10 min)

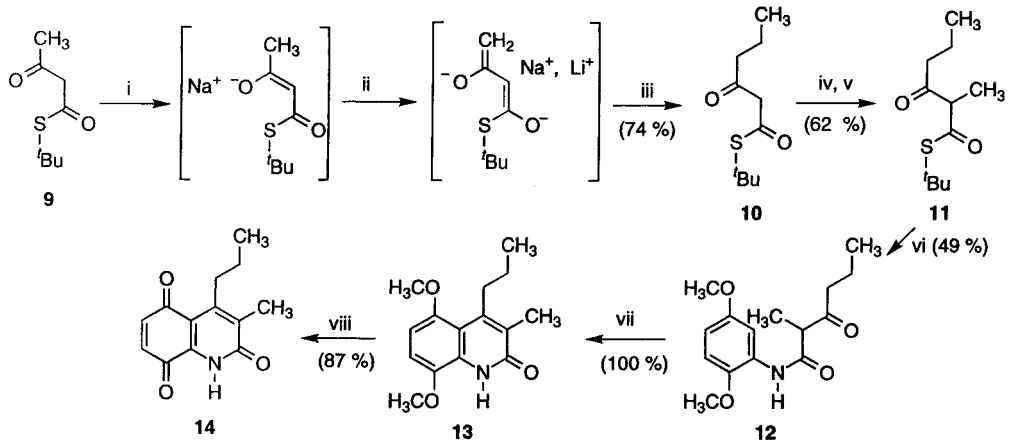
Starting material	Product	Yield (%)
 **2c**	 **3c**	77
 **2d**	 **3d**	73
 **4**	 **5**	80

unsuccessful, in agreement with the above mentioned precedent.[14] While performing these experiments, we noticed that only a small fraction of the mass of the starting material was recovered, suggesting that the failure of the reaction might be due to difficulties in the extraction of the double *N*-oxide. Therefore, we decided to use a different workup procedure, consisting of evaporation of the trifluoroacetic acid and extraction of the solid residue with chloroform. As shown in Scheme 3, this method allowed the transformation of compounds **3** into the double *N*-oxides **6**, which were characterized by ^{1}H NMR and treated without further purification with tosyl chloride in acetonitrile-water, yielding the desired 1,8-diazaanthracene-2,7,9,10-tetraones **7** in 25–40% overall yields. The rearrangement step could be controlled to yield the monolactam *N*-oxides **8** by use of a shorter reaction time. Compound **7e** was identical in all respects to natural diazaquinomycin A.[21]

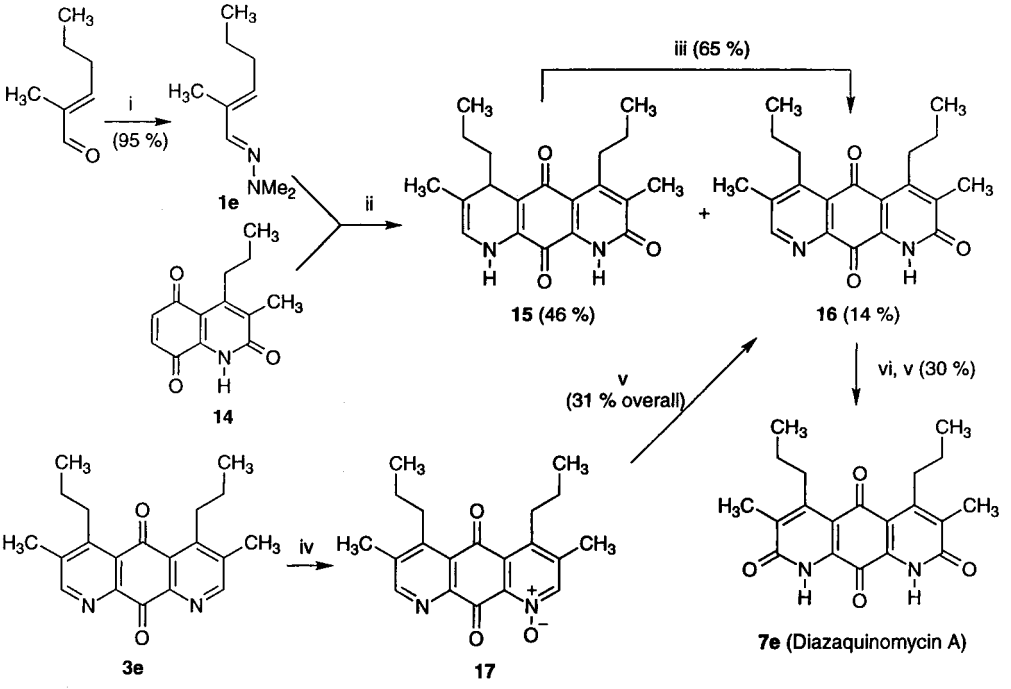
Finally, in order to explore the alternative route to diazaquinomycin A mentioned in the introduction, we prepared 3-methyl-4-propyl-2,5,8(1*H*)-quinolinetrione **14** by the method outlined in Scheme 4.[22] Regioselective alkylation[23] of the C-4 position of the dianion derived from *S*-*tert*-butyl acetothioacetate **9**[24] with ethyl bromide afforded a 74% yield of thioester **10**, which was methylated at its C-2 position via its monoanion to yield compound **11** in 62% yield.



Scheme 3. Reagents and conditions: i. H_2O_2-urea, F_3C-CO_2H, r.t., 24 h. ii. TsCl, CH_3CN, H_2O, 60°C, 24 h. iii. TsCl, CH_3CN, H_2O, 60°C, 18 h.



Scheme 4. Reagents and conditions: i. NaH, DME, −0°C, 15 min. ii. BuLi, DME, −20°C, 10 min. iii. EtBr, DME 0°C, 80 min. iv. NaH, DME, −0°C, 15 min. v. Mel, DME, 0°C, 14 h. vi. $AgCF_3CO_2$, DME, r.t., 15 h. vii. 96% H_2SO_4, r.t., 3 h. viii. $(NH_4)_2Ce(NO_3)_6$, CH_3CN, H_2O, r.t., 3 h.



Scheme 5. Reagents and conditions: i. Dimethylhydrazine, Et_2O, cat. AcOH, 45°C, 30 min. ii. Silica gel, CH_2Cl_2, r.t., 1 min, then chromatography. iii. MnO_2, CH_2Cl_2, r.t., 30 min. iv. H_2O_2-urea, F_3C-CO_2H, r.t., 18 h. v. TsCl, CH_3CN, H_2O, 60°C, 24 h. vi. H_2O_2-urea, F_3C-CO_2H, r.t., 24 h.

Amidation of **11** with 2,5-dimethoxyaniline in the presence of silver trifluoroacetate[25] afforded anilide **12** in 49% yield (97% based on unrecovered starting material). Knorr cyclization of **12** under strongly acidic conditions led to carbostyril **13** in quantitative yield, and oxidative demethylation of the latter with cerium ammonium nitrate afforded quinone **14** in 85% yield.

The azadiene necessary for the planned hetero Diels–Alder reaction, namely 2-methyl-2-hexenal dimethylhydrazone (**1e**), was prepared in 95% yield from the corresponding aldehyde[26] by treatment with dimethylhydrazine in the presence of a catalytic amount of acetic acid.[27] The reaction between **1e** and quinone **14** was carried out in a silica gel support, followed by immediate chromatography in order to prevent the addition of dimethylamine to the starting quinone,[28] a very common problem in the reactions between 1-dimethylamino-1-azadienes and quinones,[29] and afforded the 5,8-dihydro-1,8-diazaanthracene-2,9,10-trione **15** as the major product (46%), together with its aromatic derivative **16** (14%). Compound **15** was independently aromatized to **16** in 85% yield by oxidation with manganese dioxide. In order to link this route with the previous one, we also examined the transformation of 1,8-diazaanthraquinone **3e** into compound **16**. Thus, treatment of **3e** with UHP in trifluoroacetic acid for 18 h gave the mono *N*-oxide **17**, which upon

rearrangement in the presence of tosyl chloride–water afforded **16** in 31% overall yield from **3e**. Finally, compound **16** was transformed into diazaquinomycin A in 26% yield by a similar *N*-oxidation/rearrangement sequence (Scheme 5).

Experimental

All reagents were of commercial quality (Aldrich, Fluka, SDS, Probus) and were used as received with the exception of 2,5-dimethoxyaniline, which was purified by filtration through silica gel, eluting with ethyl ether. Solvents (SDS, Scharlau) were dried and purified using standard techniques. 'Petroleum ether' refers to the fraction boiling at 40–60°C. *S-tert*-butyl acetothioacetate (**11**) was prepared according to Ref. 24b. Reactions were monitored by thin layer chromatography, on aluminium plates coated with silica gel with fluorescent indicator (Macherey–Nagel Alugram Sil G/UV$_{254}$). Separations by flash chromatography were performed on silica gel (SDS 60 ACC, 230–400 mesh and Scharlau Ge 048). Melting points were measured in open capillary tubes using a Büchi inmersion apparatus, or on a Reichert 723 hot stage microsope, and are uncorrected. Infrared spectra were recorded on a Perkin–Elmer Paragon 1000 FT-IR spectrophotometer, with solid compounds compressed into KBr pellets and liquid compounds examined as films on NaCl disks. NMR spectra were obtained on Bruker AC-250 (250 MHz for ^{1}H, 63 MHz for ^{13}C) and Varian VXR-300 (300 MHz for ^{1}H, 75 MHz for ^{13}C) spectrometers, with $CDCl_3$, DMSO-d_6, CF_3COOD, pyridine-d_5, and acetone-d_6 as solvents (Servicio de Espectroscopía, Universidad Complutense). When necessary, assignments were aided by DEPT, COSY and ^{13}C-^{1}H correlation experiments. Elemental analyses were determined by the Servicio de Microanálisis, Universidad Complutense.

2-Methyl-2-hexenal dimethylhydrazone (1e)

To a solution of 2-methyl-2-hexenal[26] (0.68 g, 6.07 mmol) in Et_2O (10 mL) was added *N*,*N*-dimethylhydrazine (0.73 g, 0.92 mL, 12.14 mmol, 2 equiv.) and glacial AcOH (0.2 mL). The reaction mixture was refluxed under a $CaCl_2$ tube at 45°C for 30 min and then was warmed to room temperature and washed with aqueous $NaHCO_3$ (2×10 mL). The ether layer was dried (Na_2SO_4) and evaporated under reduced pressure at room temperature to give 0.884 g (95%) of dimethylhydrazone **6c** as a pale yellow oil. [Found: C, 69.93; H, 11.58; N, 17.92. $C_9H_{18}N_2$ requires C, 70.08; H, 11.76; N, 18.16]; ν_{max} (NaCl) 1572 cm^{-1}. δ_H (250 MHz, $CDCl_3$) 7.03 (s, 1H, H-1), 5.54 (t, 1H, J=7.4 Hz, H-3), 2.79 (s, 6H, NMe_2), 2.12 (q, 2H, J=7.4 Hz, H-4), 1.81 (s, 3H, C_2–CH_3), 1.42 (sext, 2H, J=7.2 Hz, H-5), 0.91 (t, 3H, J=7.2 Hz, H-6). δ_C (63 MHz, $CDCl_3$) 140.82 (C-1), 134.48 (C-3), 133.49 (C-2), 43.32 (NMe_2), 30.35 (C-4), 22.80 (C-5), 13.97 (C-6), 11.79 (C_2–CH_3).

Reaction of 2-methyl-2-hexenal dimethylhydrazone with 2,6-dibromobenzoquinone

To a solution of 2,6-dibromobenzoquinone[16] (200 mg, 0.75 mmol) in $CHCl_3$ (10 mL) was added the azadiene **1e** (231 mg, 1.5 mmol, 2 equiv.) and triethylamine (0.21 mL, 152 mg, 1.5 mmol, 2 equiv.). The solution was stirred at room temperature for 1 min and evaporated. The residue was washed with Et_2O (3×25 mL) yielding 306 mg (99%) of 1,8-bis-(dimethylamino)-3,6-dimethyl-4,5-dipropyl-1,4, 5,8-tetrahydro-1,8-diazaanthraquinone (**2e**),[30] which was sufficiently pure to be used without further purification.

Aromatization of 1-dimethylamino-1,4-dihydropyridine rings in the presence of UHP

General procedure. To a solution of the starting material in TFA (5 mL per mmol) was added solid UHP (3.8 equiv.). The solution was stirred at room temperature for 10 min and trifluoroacetic acid was then evaporated under reduced pressure. The residue was dissolved in 20% aqueous NH_4OH (1 mL) and extracted with $CHCl_3$ (3×25 mL). The combined organic layers were dried (Na_2SO_4) and evaporated under reduced pressure. The residue was washed with Et_2O (3×25 mL), yielding compounds **3c**–**e** and **5**.

4,5-Dimethyl-1,8-diazaanthraquinone (3c). Starting from 50 mg (0.15 mmol) of compound **2c**, a yield of 28 mg (77%) of **3c**[15] was obtained, as a pale yellow solid.

4,5-Diethyl-3,6-dimethyl-1,8-diazaanthraquinone (3d). Starting from 131 mg (0.34 mmol) of compound **2d**, a yield of 73 mg (73%) of **3d**[15] was obtained, as a pale yellow solid.

3,6-Dimethyl-4,5-dipropyl-1,8-diazaanthraquinone (3e). Starting from 340 mg (0.82 mmol) of **2e**, a yield of 193 mg (73%) of **3e** was obtained, as a pale yellow solid. [Found: C, 74.20; H, 6.76; N, 8.43. $C_{20}H_{22}N_2O_2$ requires C, 74.51; H, 6.88; N, 8.69]; mp >300°C; ν_{max} (KBr) 1677 cm^{-1}; δ_H (250 MHz, $CDCl_3$) 8.72 (s, 2H, H-2,7), 3.06 (t, 4H, J=8.0 Hz, $C_{4,5}$–CH_2–CH_2–CH_3), 2.45 (s, 6H, $C_{3,6}$–CH_3), 1.64 (m, 4H, $C_{4,5}$–CH_2–CH_2–CH_3), 1.07 (t, 6H, J=7.2 Hz, $C_{4,5}$–CH_2–CH_2–CH_3); δ_C (63 MHz, $CDCl_3$) 188.0 (C-9), 181.8 (C-10), 154.8 (C-2,7), 152.3 (C-8a,9a), 147.5 (C-10a,4a), 138.4 (C-4,5), 130.6 (C-3,6), 31.7 ($C_{4,5}$–CH_2–CH_2–CH_3), 22.9 ($C_{4,5}$–CH_2–CH_2–CH_3), 17.1 ($C_{3,6}$–CH_3), 14.7 ($C_{4,5}$–CH_2–CH_2–CH_3).

4-Methyl-1-azaanthraquinone (cleistopholine) (5). Starting from 45 mg (0.18 mmol) of compound **4**,[17] a yield of 30 mg (80%) of **5**[17,18] was obtained, as a pale yellow solid.

Double *N*-oxidation of 1,8-diazaanthraquinones

General procedure. A solution of the suitable 1,8-diazaanthraquinone **3** (95–130 mg, 0.39–0.93 mmol) and UHP (118–282 mg, equivalent to 1.25–2.99 mmol of H_2O_2) in TFA (0.85–1.15 mL) was stirred at room temperature for 4 h, with periodic additions of UHP (118–282 mg each hour, in one portion). The reaction mixture was stirred for additional 20 h and evaporated. The residue was triturated with $CHCl_3$ (8×25 mL) and the combined chloroform layers were filtered through celite and evaporated. The bis(*N*-oxides) **6** were characterized by ^{1}H NMR spectroscopy[31] and used without further purification.

Rearrangements of 1,8-diazaanthracene-9,10-dione bis-(*N*-oxides) 6

General procedures. Single rearrangement of 6a to 8a. To a suspension of compound **6a** (45 mg, 0.17 mmol) in CH_3CN (13 mL) at room temperature was added tosyl chloride (25 mg, 0.13 mmol). The suspension was slowly heated to 60°C until complete dissolution, and water (0.64 mL, 35.0 mmol) was added. The reaction mixture was stirred for 4 h, with periodic additions of tosyl chloride (25 mg, 0.13 mmol each hour). The solution was stirred for additional 14 h and cooled. A precipitate was filtered off; the filtrate was evaporated and the residue was washed with chloroform, and the orange crystalline residue was identified as compound **8a** (30 mg, 67%). [Found: C, 61.98; H, 3.57; N, 10.10. $C_{14}H_{10}N_2O_4$ requires C, 62.22; H, 3.73; N, 10.37]; mp >300°C. ν_{max} (KBr) 3423, 1676, 1640, 1188 cm^{-1}. δ_H (250 MHz, F_3CCO_2D) 8.00 (br. s, 1H, H-4), 7.44 (d, 1H, *J*=7.5 Hz, H-7), 7.02 (d, 1H, *J*=7.5 Hz, H-5), 2.13 (br. s, 6H, 2 CH_3). δ_C (63 MHz, F_3CCO_2D) 181.2 (C-9), 173.5 (C-10), 166.9 (C-2), 147.5 (C-8a), 146.5 (C-10a), 141.2 (C-3), 137.8 (C-7), 136.8 (C-9a), 131.2 (C-4), 127.4 (C-5), 122.8 (C-4a), 21.4 (C_3–CH_3), 17.5 (C_6–CH_3).

Double rearrangement to compounds 7. To a suspension of the suitable compound **6** (0.28–0.38 mmol) in CH_3CN (25–35 mL), was added tosyl chloride (54–74 mg, 0.28–0.38 mmol) at room temperature. The suspension was slowly heated to 60°C until complete dissolution, and water (1.35–1.85 mL, 75–103 mmol) was added. The reaction mixture was stirred for 4 h, with periodic additions of tosyl chloride (54–74 mg, 0.28–0.38 mmol each hour). The solution was stirred for an additional period of 20 h and was cooled. The red precipitate (compounds **7**) was filtered, washed with methanol and dried under reduced pressure. In the reaction starting from **6b**, a 13% yield of compound **8b** was obtained from the filtrate (see below).

Rearrangement of 6a. Starting from the crude bis(*N*-oxide) **6a**, previously obtained from **3a** (53 mg, 0.22 mmol), a yield of 20 mg (33% overall from **3a**) of 3,6-dimethyl-1*H*,8*H*-1,8-diazaanthracene-2,7,9,10-tetraone (**7a**) was obtained. [Found: C, 62.35; H, 3.57; N, 10.40. $C_{14}H_{10}N_2O_4$ requires C, 62.22; H, 3.73; N, 10.37]; mp >300°C; ν_{max} (KBr) 3432, 1677, 1639 cm^{-1}; δ_H (250 MHz, F_3CCO_2D) 8.20 (s, 2H, H-4,5), 2.37 (s, 6H, 2 CH_3); δ_C (63 MHz, F_3C–CO_2D) 178.1 (C-9), 171.7 (C-10), 163.5 (C-2,7), 139.6 (C-3,6), 135.5 (C-4,5), 134.8 (C-8a,9a), 117.7 (C-10a,4a), 16.9 (2 CH_3).

Rearrangement of 4b. Starting from crude bis(*N*-oxide) **6b**, previously obtained from **3b** (100 mg, 0.38 mmol), a yield of 28 mg (25% overall from **3b**) of 3,6-diethyl-1*H*,8*H*-1,8-diazaanthracene-2,7,9,10-tetraone (**7b**) was obtained. Evaporation of the methanol washes followed by trituration with $CHCl_3$ afforded a precipitate of 3,6-diethyl-1*H*-1,8-diazaanthracene-2,9,10-trione-8-oxide (**8b**) (15 mg, 13%), as an orange solid.

Data for **7b**. [Found: C, 64.31; H, 4.36; N, 9.21. $C_{16}H_{14}N_2O_4$ requires C, 64.42; H, 4.73; N, 9.39]; mp >300°C; ν_{max} (KBr) 3446, 1639 cm^{-1}; δ_H (250 MHz, F_3CCO_2D) 8.04 (s, 2H, H-4,5), 2.53 (q, 4H, *J*=7.4 Hz, $C_{3,5}$–CH_2CH_3), 1.08 (t, 6H, *J*=7.4 Hz, $C_{3,5}$–CH_2CH_3); δ_C (63 MHz, F_3C–CO_2D) 180.6 (C-9), 173.3 (C-10), 166.3 (C-2,7), 146.4 (C-3,6), 136.3 (C-8a,9a), 135.4 (C-4,5); 119.9 (C-10,4a), 24.8 ($C_{3,5}$–CH_2CH_3), 11.5 ($C_{3,5}$–CH_2CH_3).

Data for **8b**. [Found: C, 64.21; H, 4.97; N, 9.19. $C_{16}H_{14}N_2O_4$ requires C, 64.42; H, 4.73; N, 9.39]; mp >300°C; ν_{max} (KBr) 3419, 1654 cm^{-1}; δ_H (250 MHz, CD_3OD) 8.84 (s, 1H, H-4), 8.45 (s, 1H, H-7), 8.00 (s, 1H, H-5), 2.94 (q, 2H, *J*=7.4 Hz, C_6–CH_2CH_3), 2.70 (q, 2H, *J*=7.4 Hz, C_3–CH_2CH_3), 1.43 (t, 3H, *J*=7.4 Hz, C_6–CH_2CH_3), 1.33 (t, 3H, *J*=7.4 Hz, C_3–CH_2CH_3); δ_C (75 MHz, CD_3OD) 182.0 (C-9), 172.1 (C-10), 163.3 (C-2), 147.4 (C-8a), 147.0 (C-10a), 142.0 (C-6), 138.9 (C-3), 135.2 (C-9a), 134.7 (C-7), 132.1 (C-4), 131.5 (C-5), 119.8 (C-4a), 27.2 (C_6–CH_2CH_3), 25.0 (C_3–CH_2CH_3), 15.1 (C_6–CH_2CH_3), 12.8 (C_3–CH_2CH_3).

Rearrangement of 6c. Starting from crude bis(*N*-oxide) **6c**, previously obtained from **3c** (100 mg, 0.42 mmol), a yield of 28 mg (25% overall from **3c**) of 4,5-dimethyl-1*H*,8*H*-1,8-diazaanthracene-2,7,9,10-tetraone (**7c**) was obtained. [Found: C, 62.23; H, 3.61; N, 10.08. $C_{14}H_{10}N_2O_4$ requires C, 62.22; H, 3.73; N, 10.37]; mp >300°C; ν_{max} (KBr) 3420, 1670, 1637 cm^{-1}; δ_H (250 MHz, 1:1 F_3CCO_2D+$CDCl_3$) 8.77 (br. s, 2H, NH), 8.08 (s, 2H, H-3,5), 2.96 (s, 6H, 2 CH_3). δ_C (63 MHz, 1:1 F_3CCO_2D+$CDCl_3$) 176.6 (C-9), 175.6 (C-10), 166.2 (C-2,7), 142.6 (C-4,5), 136.7 (C-8a,9a), 134.5 (C-3,6), 127.3 (C-10a,4a), 21.5 (CH_3).

Rearrangement of 6d. Starting from crude bis(*N*-oxide) **6d**, previously obtained from **3d** (115 mg, 0.39 mmol), a yield of 51 mg (40% overall from **3d**) of 4,5-diethyl-3,6-dimethyl-1*H*,8*H*-1,8-diazaanthracene-2,7,9,10-tetraone (**7d**) was obtained. [Found: C, 66.20; H, 5.21; N, 8.54. $C_{18}H_{18}N_2O_4$ requires C, 66.25; H, 5.56; N, 8.58]; mp >300°C; ν_{max} (KBr) 3430, 1671, 1637 cm^{-1}; δ_H (250 MHz, F_3CCO_2D) 3.05 (q, 4H, *J*=7.5 Hz, $C_{4,5}$–CH_2CH_3), 2.18 (s, 6H, $C_{3,6}$–CH_3), 1.12 (t, 6H, *J*=7.5 Hz, $C_{4,5}$–CH_2CH_3); δ_C (63 MHz, F_3CCO_2D) 181.9 (C-9), 173.9 (C-10), 161.1 (C-2,7), 138.0 (C-3,6), 135.2 (C-8a,9a),122.2 (C-10a,4a), 25.2 ($C_{4,5}$–CH_2CH_3), 12.8 ($C_{3,5}$–CH_3), 12.5 ($C_{4,5}$–CH_2CH_3).

Rearrangement of 6e. Synthesis of diazaquinomycin A (7e, 1)

Starting from the crude bis(*N*-oxide) **6e** (130 mg, 0.40 mmol), a yield of 43 mg of **7e** (**1**) was obtained (30% overall from **3e**). This material was identical in all respects to a natural sample;[32] mp 290–295°C, lit.[1] 291–295°C; ν_{max} (KBr) 1671, 1625 cm^{-1}; δ_H (250 MHz, F_3CCO_2D) 2.99 (t, 4H, *J*=7.7 Hz, $C_{4,5}$–$CH_2CH_2CH_3$), 2.17 (s, 6H, $C_{3,6}$–CH_3), 1.44 (quint, 4H, *J*=7.5 Hz, $C_{4,5}$–$CH_2CH_2CH_3$), 0.92 (t, 6H, *J*=7.4 Hz, $C_{4,5}$–$CH_2CH_2CH_3$); δ_C (75 MHz, F_3CCO_2D) 181.1 (C-9), 173.0 (C-10), 158.9 (C-2,7), 137.1 (C-3,6), 134.3 (C-8a,9a), 121.4 (C-10a,4a), 32.9 ($C_{4,5}$–$CH_2CH_2CH_3$), 24.1 ($C_{4,5}$–$CH_2CH_2CH_3$), 13.3 ($C_{3,5}$–CH_3), 11.8 ($C_{4,5}$–$CH_2CH_2CH_3$).

***S-tert*-Butyl-3-oxohexanethioate (10)**

To a slurry of petrol-washed (2×10 mL) sodium hydride (0.76 g of a 60% dispersion in mineral oil, 18.96 mmol,

1.1 equiv.) in dry 1,2-dimethoxyethane (70 mL) under a nitrogen atmosphere at −20°C, was added dropwise, via cannula, a solution of **9**[22b] (3.00 g; 17.24 mmol) in dry dimethoxyethane (50 mL). The solution was left to warm to 0°C for 5–10 min, and then was cooled to −40°C. After 15 min at this temperature, butyl lithium (11.85 mL of a 1.6 M solution in hexanes, 18.97 mmol, 1.1 equiv.) was added dropwise, and the solution turned from yellow to dark red. The reaction was warmed to −20°C, in order to complete anion formation. After stirring for 10 min more at this temperature, it was cooled again to −40°C, and ethyl bromide (1.97 g, 18.10 mmol, 1.05 equiv.) was added. After 30 min at 0°C, the reaction mixture was quenched with saturated aqueous NH_4Cl (2×50 mL), extracted with diethyl ether (2×100 mL) and washed again with aqueous NH_4Cl (50 mL) and brine (2×50 mL), dried (Na_2SO_4), and evaporated under reduced pressure to give an orange oil. Chromatography (99% petroleum ether/ethyl ether) yielded 2.58 g (74%) of *S-tert*-butyl-3-oxohexanethioate **10** as a colourless oil. [Found: C, 59.16; H, 8.72. $C_{10}H_{18}SO_2$ requires C, 59.37; H, 8.97]; ν_{max} (NaCl) 1732 (C═O, *a*), 1684 (^{t}BuS–C═O, *a*), 1624 (C═C, *b*) cm^{-1}; δ_H ($CDCl_3$, 250 MHz, 81% oxo (*a*) and 19% enol (*b*)) 12.80 (br. s, 1H, OH, *b*), 5.25 (s, 1H, H-2, *b*), 3.48 (s, 2H, H-2, *a*), 2.44 (t, 2H, *J*=7.2 Hz, H-4, *a*), 2.03 (t, 2H, *J*=7.2 Hz, H-4, *b*), 1.53 (sext, 2H, *J*=7.3 Hz, H-5, *a*), 1.43 (s, 9H, ^{t}Bu, *b*), 1,40 (s, 9H, ^{t}Bu, *a*), 1.23–1.14 (m, 2H, H-5, *b*), 0.84 (t, 3H; *J*=7.4 Hz, H-6, *a* and *b*); δ_C ($CDCl_3$, 63 MHz) 202.3 (C-3, *a*), 196.1 (C-3, *b*), 192.6 (C-1, *b*), 176.3 (C-1, *b*), 99.6 (C-2, *b*), 58.4 (C-2, *a*), 48.9 ($C(CH_3)_3$, *a*), 48.1 ($C(CH_3)_3$, *b*), 44.9 (C-4, *a*), 36.8 (C-4, *b*), 30.2 ($C(CH_3)_3$, *b*), 29.6 ($C(CH_3)_3$, *a*), 19.6 (C-5, *b*), 16.9 (C-5, *a*), 13.6 (C-6, *b*), 13.5 (C-6, *a*).

S-tert-Butyl 2-methyl-3-oxothiohexanoate (11)

To a slurry of petrol-washed (2×10 mL) sodium hydride (0.26 g of a 60% dispersion in mineral oil, 6.50 mmol) in dry 1,2-dimethoxyethane (40 mL) under a nitrogen atmosphere at −20°C, was added dropwise, via cannula, a solution of **10** (1.25 g, 6.19 mmol) in dry 1,2-dimethoxyethane (5 mL). The solution was left to warm to 0°C for 5–10 min, and methyl iodide (0.92 g, 6.50 mmol, 1.05 equiv.) was added. After 14 h at room temperature, the reaction mixture was quenched with saturated aqueous NH_4Cl (50 mL), extracted with diethyl ether (2×100 mL) and washed again with aqueous NH_4Cl (50 mL) and brine (2×50 mL), dried (Na_2SO_4), and evaporated under reduced pressure to give an orange oil. Chromatography (99% petroleum ether/ethyl ether) yielded 0.83 g (62%) of **11** as a colourless oil. [Found: C, 60.96; H, 9.13. $C_{11}H_{20}SO_2$ requires C, 61.07; H, 9.32]; ν_{max} (NaCl) 1725 (C═O), 1673 (^{t}BuS–C═O) cm^{-1}; δ_H ($CDCl_3$, 250 MHz) 3.63 (q, 1H, *J*=6.9 Hz, H-2), 2.50 (t, 2H, *J*=7.3 Hz, H-4), 1.57 (sext, 2H, *J*=7.3 Hz, H-5), 1.46 (s, 9H, ^{t}Bu), 1.35 (d, 3H, *J*=7.0 Hz, C_2–CH_3), 0.88 (t, 3H, *J*=7.4 Hz, H-6). δ_C ($CDCl_3$, 63 MHz) 204.5 (C-3), 196.8 (C-1), 61.8 (C-2), 48.4 ($C(CH_3)_3$), 42.8 (C-4), 29.4 ($C(CH_3)_3$), 16.7 (C-5), 13.3 and 13.2 (C_6 and C_2–CH_3).

N-(2,5-Dimethoxyphenyl)-2-methyl-3-oxohexanamide (12)

To a solution of compound **11** (0.46 g, 2.13 mmol) and 2,5-dimethoxyaniline (0.34 g; 2.24 mmol; 1.05 equiv.) in 1,2-dimethoxyethane (10 mL) was added freshly prepared silver trifluoroacetate[33] (0.38 g; 1.72 mmol). After 10 min at room temperature, more silver salt (0.19 g, 0.86 mmol, totalling 1.2 equiv.) was added, and the suspension was stirred overnight at room temperature (the reaction was complete in ca. 90 min by TLC, but longer reaction times favoured the precipitation of silver species and facilitated the purification process). The dark-brown suspension was decanted from the precipitate of silver salts, which was washed with petrol (3×20–50 mL). The combined organic phases were evaporated under reduced pressure to give a black oil. Chromatography (neat dichloromethane to neat ethyl ether) yielded 0.23 g of recovered **11** and 0.29 g (49% isolated, 97% based on recovered starting material) of **12**, as a colourless oil. [Found: C, 64.59; H, 7.59; N, 5.09. $C_{15}H_{21}NO_4$ requires C, 64.50; H, 7.58; N, 5.01]; ν_{max} (NaCl) 3380 (NH), 1732 (C═O), 1692 (CO–N), 1232 (OCH_3) cm^{-1}; δ_H ($CDCl_3$, 250 MHz) 8.61 (br. s, 1H, NH), 8.03 (d, 1H, *J*=3.0 Hz, H-6′), 6.76 (d, 1H, *J*=8.9 Hz, H-3′), 6.54 (dd, 1H, *J*=8.9 and 3.0 Hz, H-4′), 3.82 (s, 3H, $C_{5'}$–OMe), 3.73 (s, 3H, $C_{2'}$–OMe), 3.55 (q, 1H, *J*=7.2 Hz, H-2), 2.55 (td, 2H, *J*=7.2 and 2.5 Hz, H-4), 1.59 (sext, 2H, *J*=7.3 Hz, H-5), 1.45 (d, 3H, *J*=7.2 Hz, C_2–CH_3), 0.87 (t, 3H, *J*=7.4 Hz, H-6); δ_C ($CDCl_3$, 63 MHz) 209.1 (C-3), 167.4 (C-1), 153.6 (C-5′), 142.3 (C-2′), 127.8 (C-1′), 110.7 (C-3′), 108.7 (C-4′), 105.9 (C-6′), 56.2 ($C_{2'}$–OMe), 55.5 ($C_{2'}$–OMe), 55.3 (C-2), 43.3 (C-4), 16.6 (C-5$_5$), 14.9 (C_2–CH_3), 13.4 (C-6).

3-Methyl-4-propyl-5,8-dimethoxy-2(1*H*)-quinolinone (13)

A solution of compound **12** (0.15 g, 0.54 mmol) in 96% H_2SO_4 (2 mL) was stirred at room temperature for 3 h, and was then quenched with ice, basified with 25% aqueous NH_4OH and extracted with $CHCl_3$ (3×25–50 mL). The combined organic layers were washed with brine (25–50 mL), dried (Na_2SO_4) and evaporated under reduced pressure to give an off-white solid. Chromatography (50% ethyl ether/ethyl acetate to neat ethyl acetate) afforded 0.14 g (100%) of compound **13** as white crystals. [Found: C, 68.68; H, 7.31; N, 5.18. $C_{15}H_{19}NO_3$ requires C, 68.94; H, 7.33; N, 5.36]; mp 171–173°C; ν_{max} (KBr) 3190 (NH), 1644 (C═O), 1268 (OCH_3) cm^{-1}; δ_H ($CDCl_3$, 250 MHz) 9.27 (br. s, 1H, NH), 6.79 (d, 1H, *J*=8.8 Hz, H-7), 6.50 (d, 1H, *J*=8.8 Hz, H-6), 3.88 and 3.84 (2 s, 6H, 2OMe), 3.05 (t, 2H, *J*=7.9 Hz, C_4–CH_2), 2.24 (s, 3H, C_3–CH_3), 1.55 (sext, 2H, *J*=7.9 Hz, C_4–CH_2–CH_2), 1.03 (t, 3H, *J*=7.3 Hz, C_4–CH_2–CH_2–CH_3); δ_C ($CDCl_3$, 63 MHz) 161.6 (C-2), 151.1 (C-5), 148.9 (C-8), 139.6 (C-4), 128.4 (C-8a), 127.1 (C-3), 111.3 (C-4a), 108.4 (C-7), 102.2 (C-6), 56.1 and 55.7 (2 OMe), 34.1 (CH_2–CH_2–CH_3), 22.8 (CH_2–CH_2–CH_3), 14.5 (CH_2–CH_2–CH_3), 12.2 (C_3–CH_3).

3-Methyl-4-propyl-1*H*-2,5,8-quinolinetrione (14)

To a solution of compound **13** (0.18 g, 0.70 mmol) in a mixture of CH_3CN (10 mL) and H_2O (5 mL) was added cerium ammonium nitrate (1.16 g, 2.10 mmol, 3 equiv.). The solution was stirred at room temperature for 3 h, and was then diluted with H_2O (15 mL) and extracted with $CHCl_3$ (3×30 mL). The chloroform layer was washed with H_2O (2×40 mL), dried (Na_2SO_4) and evaporated under

reduced pressure to give a red residue. Sublimation at 0.1 torr yielded 0.14 g (87%) of quinone **14** as a dark orange solid. [Found: C, 67.56; H, 5.83; N, 5.80. $C_{13}H_{13}NO_3$ requires C, 67.52; H, 5.67; N, 6.06]; mp 144–146°C; ν_{max} (KBr) 3450 (NH), 1652 (C═O) cm^{-1}; δ_H ($CDCl_3$, 250 MHz) 9.47 (br. s, 1H, NH); 6.84 (d, 1H, *J*=10.2 Hz, H-7), 6.76 (d, 1H, *J*=10.2 Hz, H-6), 2.99 (t, 2H, *J*=7.9 Hz, C_4–C*H*$_2$), 2.22 (s, 3H, C_3–C*H*$_3$), 1.49 (sext, 2H, *J*=7.8 Hz, C_4–CH_2–C*H*$_2$–CH_3), 1.06 (t, 3H, *J*=7.3 Hz, C_4–CH_2–CH_2–C*H*$_3$); δ_C ($CDCl_3$, 63 MHz) 183.8 (C-8), 179.5 (C-5), 161.2 (C-2), 150.0 (C-4), 140.3 (C-6), 136.1 (C-8a), 134.9 (C-3), 132.4 (C-7), 113.9 (C-4a), 31.7(C_4–*C*H$_2$), 22.2 (C_4–CH_2–*C*H$_2$–CH_3), 14.34 (C_4–CH_2–CH_2–*C*H$_3$), 12.35 (C_3–*C*H$_3$).

Reaction of 3-methyl-4-propyl-1*H*-2,5,8-quinolinetrione (14) with 2-methyl-2-hexenal dimethylhydrazone (1e)

Silica gel (125 mg) was added to a solution of quinone **14** (40 mg, 0.17 mmol) in $CHCl_3$ (10 mL). The suspension was stirred at room temperature for 15 min and evaporated to dryness. The silica gel-supported quinone was placed on the top of a chromatography column containing silica gel (6 g) and was covered with a layer of sand. Neat 2-methyl-2-hexenal dimethylhydrazone **1e** (53 mg, 0.35 mmol, 2 equiv.) was added and covered with a second layer of sand. The diene was allowed to permeate the sand and contact the silica gel layer over 1 min. The column was then eluted with a gradient from dichloromethane to 1:1 dichloromethane-ethyl acetate, to yield recovered azadiene **1e**, 27 mg (46%) of 5,8-dihydro-3,5-dimethyl-4,5-dipropyl-1*H*-1,8-diazaanthracene-2,9,10-trione (**15**) as a green solid and 14 mg (24%) of 3,5-dimethyl-4,5-dipropyl-1,8-diazaanthracene-2,9,10-trione (**16**) as a yellow solid.

Data for **15**. [Found: C, 70.38; H, 6.95; N, 8.01. $C_{20}H_{24}N_2O_3$ requires C, 70.57; H, 7.11; N, 8.23]; mp 179–180°C; ν_{max} (KBr) 3420 (NH), 1654, 1636 (C═O) cm^{-1}; δ_H ($CDCl_3$, 250 MHz) 9.79 (br. s, 1H, NH), 6.64 (br. s, 1H, H-8), 6.06 (d, 1H, *J*=4.2 Hz, H-7), 3.62 (t, 1H, *J*=4.7 Hz, H-5), 3.21–2.95 (m, 2H, C_4–C*H*$_2$), 2.23 (s, 3H, C_3–C*H*$_3$), 1.74 (s, 3H, C_6–C*H*$_3$), 1.51–1.42 (m, 4H, C_4–CH_2–C*H*$_2$ and C_5–CH_2–C*H*$_2$), 1.34–1.24 (m, 2H, C_5–C*H*$_2$), 1.06 (t, 3H, *J*=7.1 Hz, C_4–CH_2–CH_2–C*H*$_3$), 0.94–0.76 (m, 3H, C_5–CH_2–CH_2–C*H*$_3$); δ_C ($CDCl_3$, 63 MHz) 183.5 (C-9), 175.9 (C-10), 161.2 (C-2), 151.1 (C-4), 136.5, 135.8 and 134.2 (C_{8a}, C_{9a} and C_3), 119.37 (C-7), 116.00 (C-6), 114.83 (C-4a), 112.6 (C-10a), 35.9 (C_4–*C*H$_2$), 35.6 (C-5), 32.2 (C_5–*C*H$_2$), 22.6 (C_4–CH_2–*C*H$_2$), 18.9 (C_5–CH_2–*C*H$_2$–CH_3), 18.6 (C_6–*C*H$_3$), 14.6 and 14.4 (C_4–CH_2–CH_2–*C*H$_3$ and C_5–CH_2–CH_2–*C*H$_3$), 12.82 (C_3–*C*H$_3$).

Data for **16**. [Found: C, 70.75; H, 6.53; N, 7.99. $C_{20}H_{22}N_2O_3$ requires C, 70.99; H, 6.55; N, 8.28]; mp 170–172°C; ν_{max} (KBr) 3421 (NH), 1654 and 1636 (C═O) cm^{-1}; δ_H ($CDCl_3$, 250 MHz) 9.67 (br. s, 1H, NH), 8.69 (s, 1H, H-7), 3.12–2.99 (m, 4H, C_4–C*H*$_2$ and C_5–C*H*$_2$), 2.46 (s, 3H, C_6–C*H*$_3$), 2.26 (s, 3H, C_3–C*H*$_3$), 1.67–1.45 (m, 4H, C_4–CH_2–C*H*$_2$ and C_5–CH_2–C*H*$_2$), 1.10 and 1.08 (2 t, 6H, *J*=7.3 and 7.1 Hz, C_4–CH_2–CH_2–C*H*$_3$ and C_5–CH_2–CH_2–C*H*$_3$). δ_C ($CDCl_3$, 63 MHz) 184.3 (C-9), 177.1 (C-10), 160.9 (C-2), 154.2 (C-7), 152.8 (C-4), 149.9 (C-5), 145.4 (C-8a), 139.6 (C-9a), 136.3 and 136.1 (C-6 and C-3), 129.5 (C-10a), 117.9 (C-4a), 32.1 and 31.6 (C_4–*C*H$_2$ and C_5–*C*H$_2$), 22.6 and 22.5 (C_4–CH_2–*C*H$_2$ and C_5–CH_2–*C*H$_2$), 17.2 (C_6–*C*H$_3$), 14.5 and 14.3 (C_4–CH_2–CH_2–*C*H$_3$ and C_5–CH_2–CH_2–*C*H$_3$), 12.7 (C_3–*C*H$_3$).

Preparation of (16) by aromatization of (15)

To a solution of compound **15** (25 mg, 0.07 mmol) in CH_2Cl_2 (10 mL) was added 38 mg (0.39 mmol, 5 equiv.) of activated 85% manganese dioxide. The suspension was stirred at room temperature for 30 min and then was filtered through celite, which was washed twice with $CHCl_3$ (30 mL). The combined organic layers were evaporated under reduced pressure to give a brown residue. Chromatography (ethyl acetate) afforded 16 mg (65%) of the aromatic compound **16** as a yellow solid.

Alternative synthesis of compound (16) from (3e)

A solution of compound **3e** (60 mg, 0.19 mmol) and UHP (54.6 mg, equivalent to 0.58 mmol of H_2O_2) in trifluoroacetic acid (0.5 mL) was stirred at room temperature for 4 h, with periodic additions of fresh UHP (54.6 mg each hour). Stirring at room temperature was prolonged for additional 14 h. The reaction mixture was then evaporated and the residue was trirurated with $CHCl_3$ (8×25 mL). The combined organic layers were filtered through celite and evaporated, affording compound **17** as an orange solid, which was identified by ^1H RMN and used without further purification. The crude compound **17**[34] was dissolved in TFA (1 mL) and submitted to the general procedure for the rearrangement of *N*-oxides to lactams described above, yielding compound **16** (20 mg, 31% overall).

Synthesis of diazaquinomycin A from (16)

A solution of compound **16** (19 mg, 0.056 mmol) and UHP (17.3 mg, equivalent to 0.18 mmol of H_2O_2) in TFA (0.15 mL) was stirred at room temperature for 4 h, with hourly additions of fresh UHP (17.3 mg each time). Stirring at room temperature was prolonged for additional 14 h; the reaction mixture was then evaporated and the residue was triturated with $CHCl_3$ (8×25 mL). The combined organic layers were evaporated and the residue was suspended in CH_3CN (5 mL). The suspension was treated with tosyl chloride (10.8 mg, 0.056 mmol) and the temperature was raised to 60°C, until dissolution. Water (0.3 mL, 16.6 mmol) was added, and the solution was stirred at 60°C for 4 h, with hourly additions of tosyl chloride (10.8 mg each time). After an additional reaction time of 20 h at 60°C, the solution was cooled. A red precipitate was filtered, washed with methanol and dried in vacuo. This material (6 mg, 30% overall from **16**) was identical in all respects to natural diazaquinomycin A.

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30. δ_H (250 MHz, $CDCl_3$) 6.04 (s, 2H), 3.40 (t, 2H, J=4.5 Hz), 2.58 (s, 6H), 1.66 (s, 6H), 1.12 (m, 4H), 1.01 (m, 4H), 0.81 (t, 6H, J=7.5 Hz).
31. δ_H (250 MHz, $CDCl_3$): **4a**: 8.41 (s, 2H, H-2,7), 7.99 (s, 2H, H-4,5), 2.54 (s, 6H, $C_{3,6}$–CH_3); **4b**: 8.36 (s, 2H, H-2,7), 7.94 (s, 2H, H-4,5), 2.77 (m, 4H, $C_{3,6}$-CH_2–CH_3), 1.28 (t, 6H, J=6.2 Hz, $C_{3,6}$–CH_2-CH_3). **4c**: 7.90 (d, 2H, J=8.5 Hz, H-2,7), 7.07 (d, 2H, J=8.5 Hz, H-3,6), 2.83 (s, 6H, $C_{4,5}$–CH_3), **4d**: 8.35 (s, 2H, H-2,7), 3.06 (m, 4H, $C_{4,5}$–CH_2–CH_3), 2.44 (s, 6H, $C_{3,6}$–CH_3), 1.30 (t, 6H, J=7.1 Hz, $C_{4,5}$–CH_2-–CH_3); **4e**: 8.26 (s, 2H, H-2,7), 2.88 (m, 4H, $C_{4,5}$–CH_2–CH_2–CH_3), 2.38 (m, 4H, $C_{4,5}$–CH_2–CH_2–CH_3), 2.13 (s, 6H, $C_{3,6}$–CH_3), 1.07 (t, 6H, J=7.1 Hz, $C_{4,5}$–CH_2–CH_2–CH_3).
32. The synthetic material was directly compared with a natural sample. Literature NMR data for diazaquinomycin A (Ref. 1b) were obtained in an unspecified mixture of CD_3OD and $CDCl_3$, which explains the slight differences with our data.
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