Dioxopyrrolines. XLIX.[1] Synthesis of Azatropolones *via* Photocycloaddition of 5-Aryl-4-ethoxycarbonyl-1*H*-pyrrole-2,3-diones to Acetylenes and Ethylenes

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The first synthesis of derivatives of azatropolone, a new nitrogen heterocycle, and some of their chemical properties are described. Two routes to the azatropolone skeletone were developed; one is the photocycloaddition of dioxopyrrolines 1 to acetylenes followed by thermolysis or photolysis of the resulting cyclobutenes 2 to give the azatropolones 7 or 8, and the other is the ring expansion reaction of the cyclobutanes 5 obtained by the photocycloaddition of 1 to olefins followed by 2,3-dichloro-5,6-dicyano-1,4-benzoquinone dehydrogenation of the resulting dihydroazepines 16 to give the azatropolones 7.

The azatropolone rapidly consumed diazomethane; thus 7 gave the 3-*O*-methylazatropolones 18, while 8 gave mixtures of 3-*O*-methyl-19 and 2-*O*-methylazatropolones 20. The position of methylation was proved by the unambiguous synthesis of 18 and of 2-*O*-ethyl derivatives 24 from 16. The azatropolones 7 and 8, when treated with a protonic solvent, readily underwent a ring contraction reaction giving rise to the pyridine-2-carboxylates 29 and 30, respectively, thus demonstrating that the azatropolone nucleus has a strongly electrophilic character.

Keywords dioxopyrroline; photocycloaddition; cyclobutane; synthesis; azatropolone; 2*H*-azepin-2-one; 3*H*-azepin-3-one; electrophilicity; ring contraction; pyridine-2-carboxylate

Seven membered heterocycles have been extensively investigated because of their chemical features involving the aromaticity and valence isomerizations,[2] and also because of the biological and pharmaceutical activities found in, particularly, seven-membered nitrogen heterocycles such as azepine (muscaflavin[3]), benzoazepine (cepharotaxine[4]), and 1,4-benzodiazepine (antramycine[5] and chlordiazepoxide[6]) derivatives. Although many azepines and azepinones[7] including annelated derivatives[8] have been synthesized, the fully unsaturated monocyclic azepinones have only a few precedents; those are i,[9,10] ii,[10] iii,[11] and iv[12] shown in Chart 1. The fully unsaturated 3-hydroxy-2*H*-azepin-2-one, so called azatropolone (α-tropolone *N*-analog), is hitherto unknown. In this paper we treat the synthesis of azatropolone derivatives and some of their chemical properties.[13]

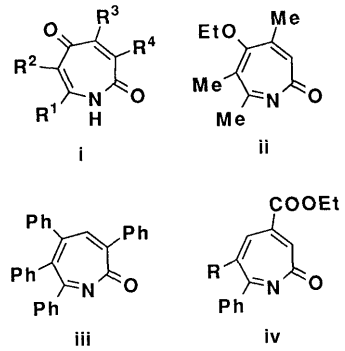


Chart 1

In relation to our synthetic studies of nitrogen heterocycles using 1*H*-pyrrole-2,3-diones (dioxopyrrolines), we planned to synthesize azatropolones by two routes as shown in Chart 2. The azatropolone (C) is a valence bond isomer of 2-azabicyclo[3.2.0]hept-6-ene-3,4-dione (B). This cyclobutene could be derived by photoannulation of dioxopyrroline (A) to acetylenes. The azabicyclo[3.2.0]-heptane-3,4-dione (D) is a valence bond isomer of dihydroazatropolone (E) which could be transformed into the azatropolone (C) by dehydrogenation. The preparation of cyclobutane derivatives of this type has been achieved by the photocycloaddition of 5-aryl-4-ethoxycarbonyl-1*H*-pyrrole-2,3-diones **1** to olefins.[14]

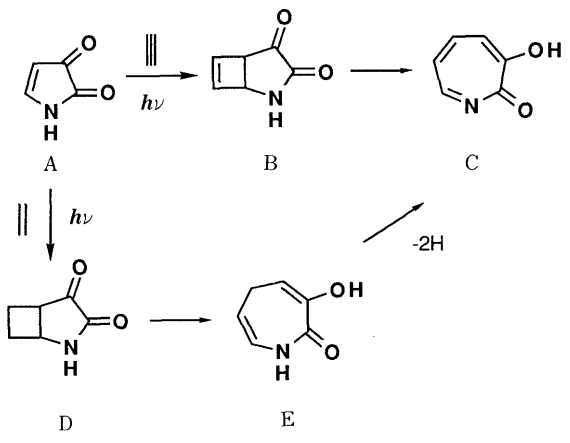


Chart 2

Results and Discussion

Photocycloaddition of Phenylacetylene to the Dioxopyrroline 1 Irradiation of a solution of the dioxopyrroline **1a** and phenylacetylene in dimethoxyethane (DME) with ≧300 nm light at 0 °C for 45 min gave three adducts, the cyclobutene **2a** (40%), the pyridone **3a** (9%), and the pyrido-phenanthrene **4** (1%). A similar photocycloaddition of the *N*-methyldioxopyrroline **1b** to phenylacetylene gave the cyclobutene **2b** (20%) and the pyridone **3b** (5%). Similar irradiation of a solution of 5-(*p*-bromophenyl)dioxopyrroline **1c** and phenylacetylene gave the cyclobutene **2c** (13%) and the pyridone **3c** (4%) (Chart 3).

The cyclobutenes **2a—c** were proved to be 1 : 1 adducts of the two addends by their elementary analyses and mass spectra. In the proton-nuclear magnetic resonance (^{1}H-NMR) spectra they showed an olefinic proton signal at δ 6.55 for **2a**, 6.72 for **2b**, and 6.47 for **2c**, suggesting the

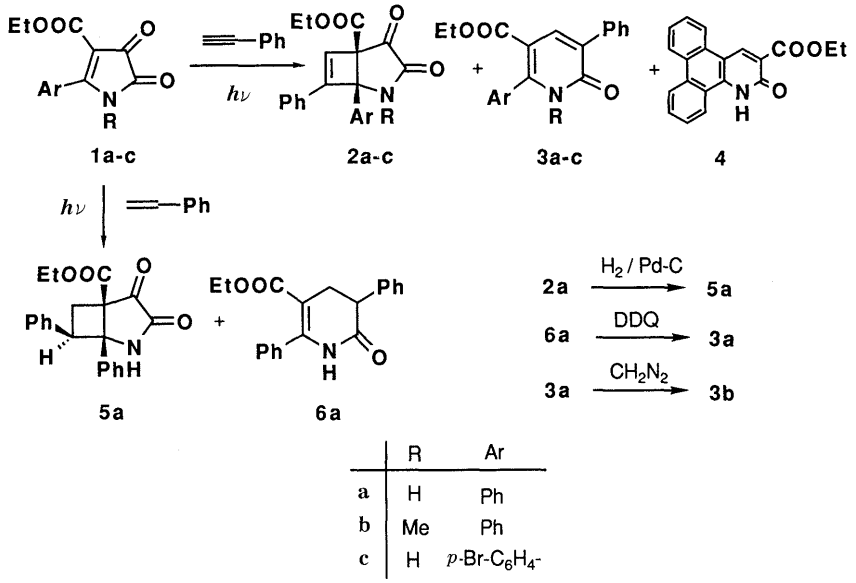


Chart 3

cyclobutene structure. The regiochemistry of the adduct was unambiguously proved by the fact that catalytic hydrogenation of **2a** over 10% Pd–C yielded the cyclobutane **5a**, a photo-adduct of **1a** to styrene, whose structure was proved previously.[14]

The adducts **3a**—**c** have the molecular formulae corresponding to the 1 : 1 adduct minus CO. The presence of the pyridone moiety was indicated by the ultraviolet (UV) (λ_{max} 290 and 328 nm for **3a**, 284 and 324 nm for **3b**, and 280 and 328 nm for **3c**) and the infrared (IR) (ν_{max} 1670 cm^{-1} for **3a**, 1647 cm^{-1} for **3b**, and 1650 cm^{-1} for **3c**) spectra. This structural assignment was established by the fact that 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) oxidation of the known dihydropyridone **6a**[14] gave the pyridone **3a**. Methylation of **3a** with diazomethane gave the *N*-methyl derivative, which was identical with the photo-adduct **3b** described above.

The structure of the minor adduct **4** was assigned from the molecular formula, UV, and ^{1}H-NMR spectra (see Experimental).

Synthesis of Azatropolones by Pyrolysis or Photolysis of the Cyclobutenes 2 The ring expansion of the cyclobutenes **2** smoothly occurred on pyrolysis. Thus, **2a** on heating at 160 °C in toluene gave the azatropolone **7a** as yellow prisms in 60% yield. A similar thermal ring expansion reaction of **2b** gave the *N*-methylazatropolone **7b** in 70% yield.

Photolysis of **2** yielded an isomeric azatropolone. Irradiation of **2a** in DME at 0 °C followed by rapid column chromatography of the product over silica gel gave the azatropolone **8a** (11%) along with the pyridone **3a** (10%). However, similar irradiation of **2b** failed to give the corresponding *N*-methylazatropolone **8b** and no characterizable product was obtained.

Compounds **7a** and **8a** were concluded to be azatropolones from the following evidence. i) They have the expected molecular formula, $C_{21}H_{17}NO_4$, as proved by high resolution mass spectra and elementary analyses. In the mass spectra (MS) they showed a strong peak corresponding to $M^+ - CO$, as expected in the fragmentation of α-tropolone.[15] Particularly, in the case of **8a** the

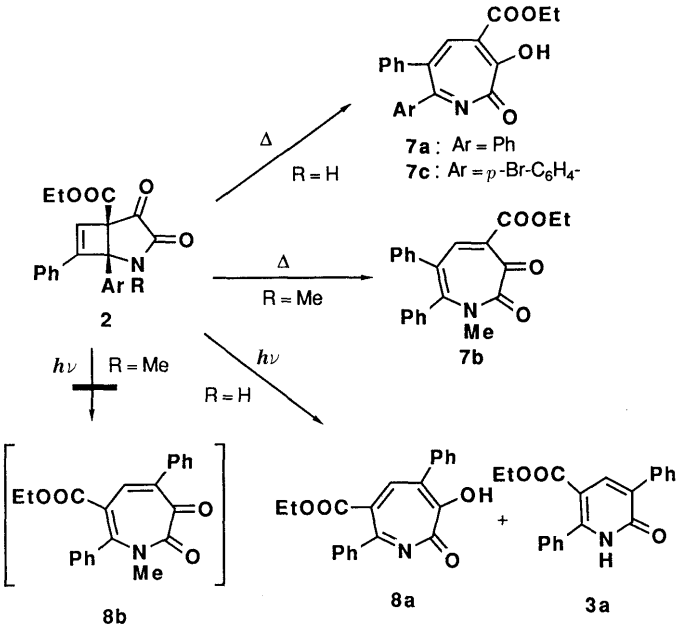


Chart 4

fragmentation pattern below the ($M^+ - CO$) peak was almost superimposable on that of the pyridone **3a** except for a few minor peaks. This fact strongly suggests that **8a** has an azatropolone structure with a similar substitution pattern to **3a**, as shown in Chart 5. ii) In the UV spectra they exhibited strong absorptions in the visible region as shown in Fig. 1. iii) In the ^{1}H-NMR spectra the azatropolone ring proton was observed at fairly low field (δ 8.00 for **7a** and 7.68 for **8a**). This signal in **7a** was attributed to the C_5-proton, and this assignment was verified by comparison of the ^{1}H-NMR spectrum of the 5-deuterio-azatropolone **7D** which lacked the corresponding proton signal. The compound **7D** was prepared by similar thermolysis of the deuterated cyclobutene **2D**.[16] iv) Finally, the structure of **7a** was established by the X-ray crystallographic analysis of its 3-*O*-methyl derivative **18c**[13b] (see Chart 10), which was prepared by methylation

of the 7-(*p*-bromophenyl) azatropolone **7c**. As shown in Chart 6, the X-ray crystallographic structure of **18c** revealed that the 3-*O*-methylazatropolone nucleus is not planar but puckered. The C_2 carbonyl carbon deviates by 0.8 Å from the best plane formed by C_3–C_7 and N.

Here we wish to discuss how the azatropolones **7a** and **8a**, and other photo-products **3a** and **4** were formed. The azatropolone **7a** is obviously a ring expansion product formed through a 4π-electrocyclic reaction of the cyclobutene **2a**. On the other hand, the other azatropolone **8a** can be rationalized as a ring expansion product of the isomeric cyclobutene **10** which must be produced by bond recombination between the C_4 and C_7 positions of the mesomeric biradical **9**, being generated by the homolytic fission of the C_4–C_5 bond of **2a**. The ring expansion process of **10** to **8a** takes place probably in a thermal process.

The pyridone **3a** may be formed by a 1,3-shift of the C_1–C_7 bond to the 3-carbonyl carbon, followed by cheletropic

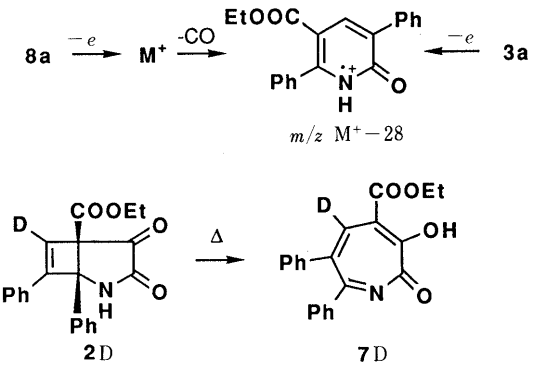
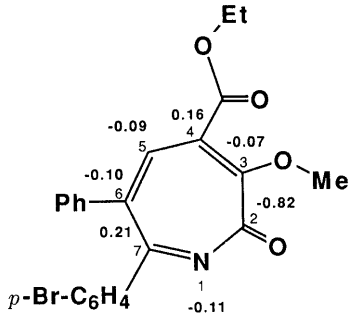


Chart 5



deviation (Å) from the average plane formed by C_3-C_7 and N

Chart 6

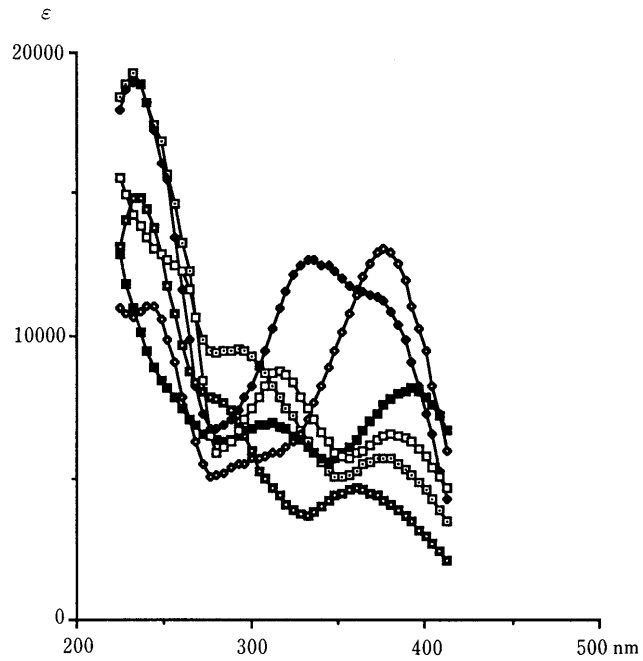


Fig. 1. UV Spectra of the Azatropolones **7** and **8** in Dioxane
—⊡—, **7a**; —●—, **8a**; —□—, **7b**; —○—, **7e**; —■—, **7d**; —□—, **8d**.

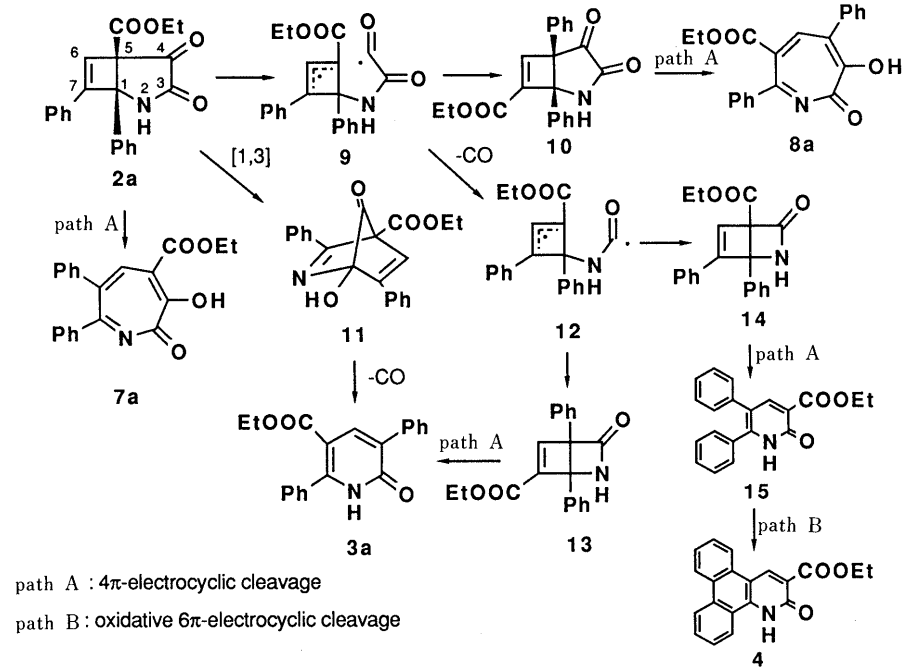


Chart 7

loss of CO from the resulting azanorbornene **11**. A similar reaction was observed in the photocycloaddition reaction of **1** with olefins.[14,17] Another possible pathway to **3a** is a 4π-electrocyclic ring-opening process of the azabicyclohexene **13** which can be formed from the norbiradical **12**.

The pyrido-phenanthrene **4** is an oxidative photocyclization product of 6π-electrocyclic reaction of the isomeric pyridone **15** which may be formed by the bond recombination of **12** followed by ring expansion of the resulting azabicyclohexene **14**.

Photocycloaddition of Other Acetylenes to the Dioxopyrroline 1a A solution of **1a** and ethoxyacetylene in DME was irradiated at 0 °C to give the azatropolone **8d** (27%) together with the pyridone **3d** (22%). In this case the cyclobutene **2d** was not isolated from the reaction mixture. This azatropolone was found to be isomeric with the azatropolone **7d** which was prepared by DDQ oxidation of the 1,5-dihydro-2*H*-azepin-2-one **16d** described in the next section, thus proving the structure.

The structure of the pyridone **3d** was proved as follows. DDQ oxidation of the known dihydropyridone **6d**, a photo-product of **1a** to ethoxyethylene,[14] gave the dehydro derivative which was identical with **3d**.

Photocycloaddition of **1a** to acetylene did not give any characterizable adduct under similar irradiation conditions.

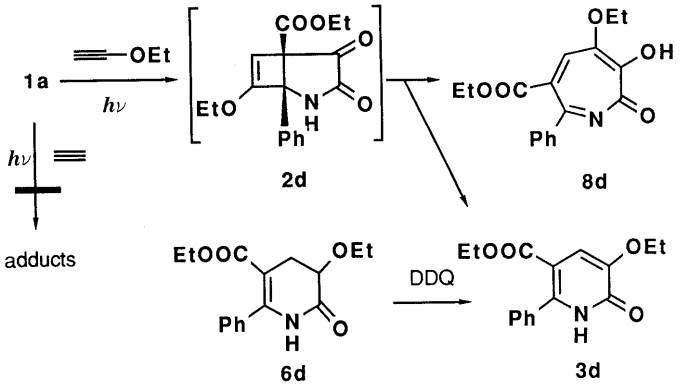


Chart 8

Synthesis of Azatropolones from the Olefin-Photoadducts Various 7-substituted 2-azabicyclo[3.2.0]heptane-3,4-diones **5a, d, f—i** were prepared by the photoannulation of **1a** with olefins.[14] The ring expansion of these cyclobutanes **5** to 3-hydroxy-1,5-dihydro-2*H*-azepin-2-ones **16** by C_1–C_5 bond fission was effectively achieved on treatment with 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) in benzene in good yields.[18]

The 6-H derivative **16e** was prepared by treatment of the 6-SPh derivative **5g** with Raney Ni in EtOH. The reaction caused ring expansion together with reductive desulfurization. Although the yield was not high (53%), the product was otherwise hardly accessible.

Compounds **16** showed a strong absorption at around 260—270 nm in their UV spectra and exhibited a signal due to C_5-methylene protons as a singlet in their ^{1}H-NMR

Table I. Dehydrogenation of 3-Hydroxy-1,5-dihydro-2*H*-azepin-2-ones **16**, 3-Methoxy-1,5-dihydro-2*H*-azepin-2-one **21**, and 7-Ethoxy-4*H*-azepines **23** with DDQ in Benzene

Compound (R)	Conditions Temp.	Time (min)	Yield (%) (Product)
16a (Ph)	100	45	2[a] (**7a**)
16d (OEt)	100	25	65 (**7d**)
16e (H)	100	5	50 (**7e**)
16f (OAc)	100	45	5[a] (**7f**)
16g (SPh)	100	45	5[a] (**7g**)
16h (Et)	100	45	17[a] (**7h**)
21a (Ph)	120	120	40 (**18a**)
21d (OEt)	100	30	50 (**18d**)
21e (H)	100	3	50[b] (**18e**)
21f (OAc)	120	90	40 (**18f**)
21g (SPh)	110	120	48 (**18g**)
21h (Et)	120	90	45 (**18h**)
23a (Ph)	105	8	77 (**24a**)
23d (OEt)	25	<2	43 (**24d**)
23e (H)	25	<2	62 (**24e**)
23f (OAc)	110	20	60 (**24f**)

a) The yield was calculated from that of the methyl pyridine-2-carboxylate **29**M. *b*) Compound **18e** was not isolated in a pure form, but the yield was calculated from that of the azatropolone **7e**.

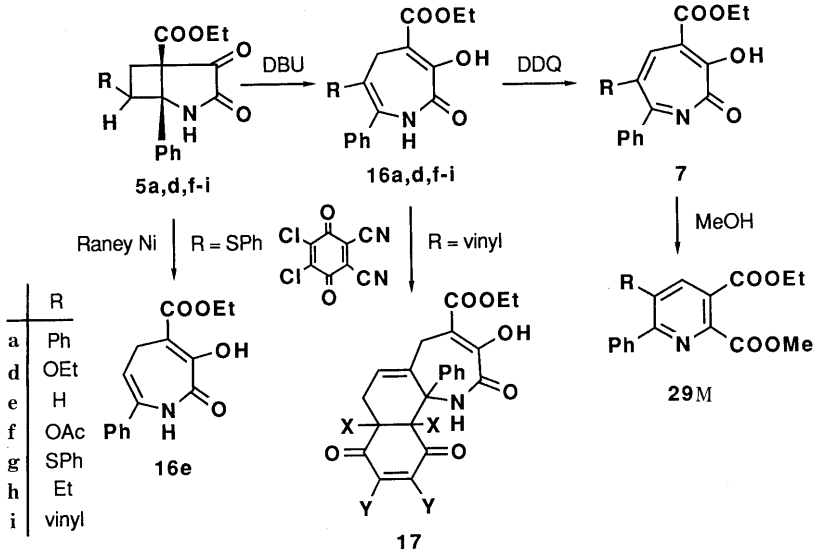


Chart 9

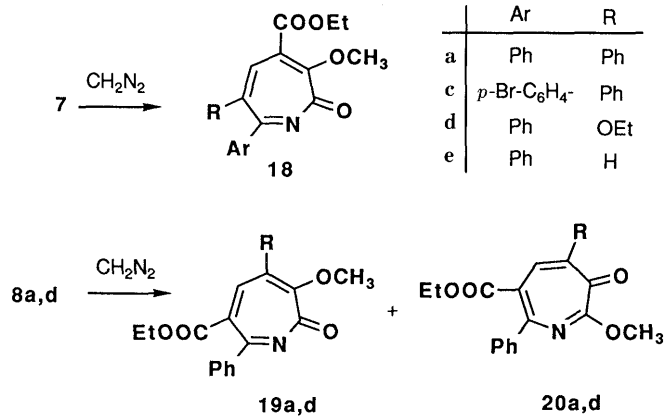


Chart 10

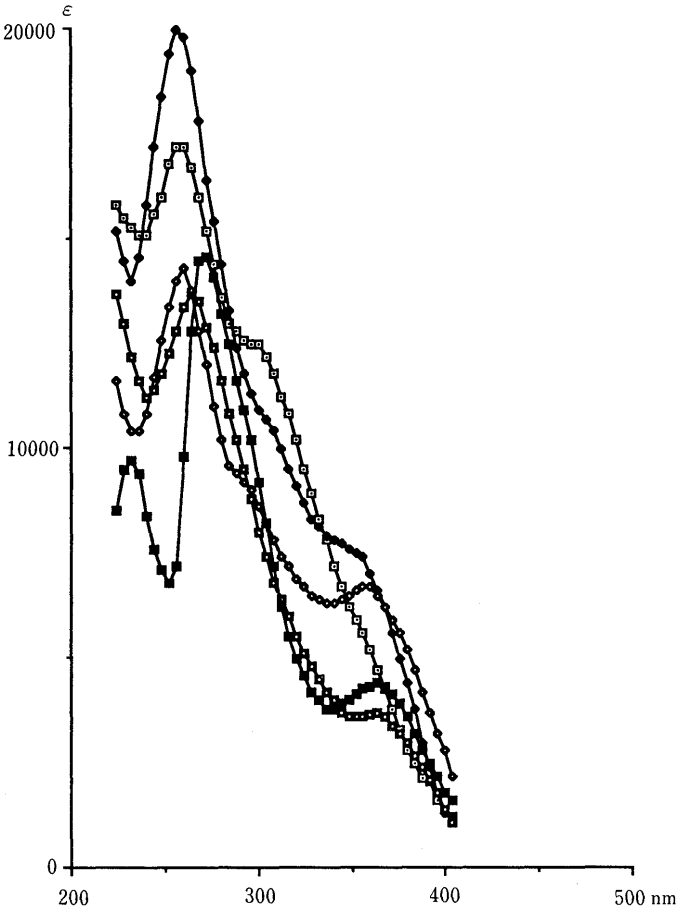


Fig. 2. UV Spectra of 3-*O*-Methylazatropolones in Dioxane
—⊡—, **18a**, —◆—, **19a**; —□—, **18d**; —◇—, **19d**; —■—, **27**.

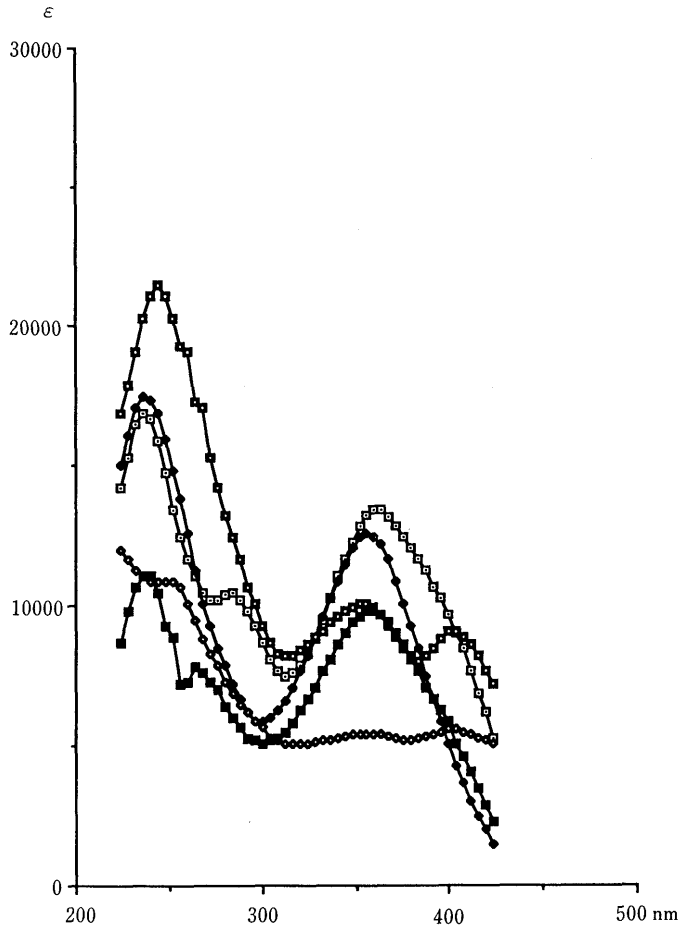


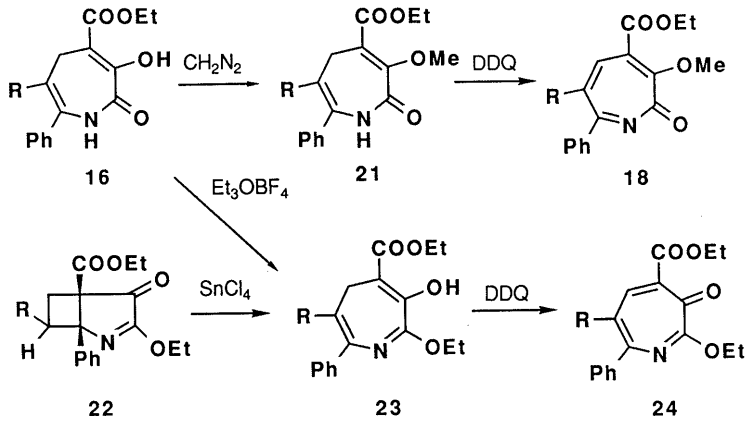
Fig. 3. UV Spectra of 2-*O*-Methyl- and 2-*O*-Ethylazatropolones in Dioxane
—⊡—, **20a**; —●—, **20d**; —□—, **24a**; —◇—, **24d**; —■—, **28**.

spectra, indicating that the 3-ketone is completely enolized. Thus, the skeleton of **16** was assigned as 3-hydroxy-1,5-dihydro-2*H*-azepin-2-one.

Dehydrogenation of **16** except for **16i** was achieved by DDQ oxidation, but the reaction was greatly affected by the nature of 6-substituents. The oxidation of the 6-OEt **16d** and 6-H **16e** derivatives smoothly occurred to give the corresponding azatropolones **7d** and **7e** in moderate yields, while the dehydrogenation of the 6-Ph **16a**, 6-OAc **16f**, 6-SPh **16g**, and 6-Et **16h** derivatives to the corresponding azatropolones **7a** and **7f—h** was difficult and the yields were lower. In these cases the azatropolones could not be isolated in pure forms from the reaction mixture because of their instability under solvolytic conditions. Therefore, their formation was demonstrated by the isolation of methyl pyridine-2-carboxylates **29**M after treatment of the crude oxidation products with methanol (details are described in the last section). The results are accumulated in Table I. The UV spectra of **7d** and **7e** (see Fig. 1) together with other spectral data supported their azatropolone structures.

When the 6-vinyl derivative **16i** was heated with DDQ in toluene, a Diels–Alder reaction occurred to give the adduct **17**, instead of the expected dehydrogenation product. The structure of the product was deduced from its elementary analysis and spectral data.

Syntheses of Azatropolone *O*-Alkyl Derivatives Methylation of the azatropolones **7a**, **7c**, **7d** and **7e** with diazomethane occurred readily and regioselectively at the C_3 oxygen to give the 3-*O*-methylazatropolones (3-methoxy-2*H*-azepin-2-ones) **18a**, **18c**, **18d** and **18e** as sole products. On the other hand, similar methylation of the azatropolones **8a** and **8d** occurred at both C_3- and C_2-oxygen to give a mixture of the 3-*O*-methyl **19a** and **19d** and the 2-*O*-methyl **20a** and **20d** derivatives (2-methoxy-3*H*-azepin-3-ones) in about 1 : 1 ratio. The position of methylation was determined by the syntheses of **18** and 2-*O*-ethylazatropolones **24** *via* unambiguous routes from **16** as follows.



a : R=Ph d : R=OEt e : R=H f : R=OAc g : R=SPh
h : R=Et

Chart 11

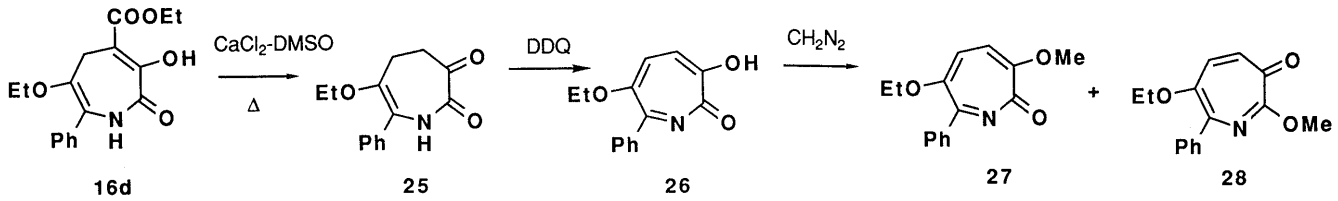


Chart 12

Methylation of **16** with diazomethane took place at the enolic 3-OH to give the methyl ether (3-methoxy-1,5-dihydro-2*H*-azepin-2-one) **21**. On the other hand, ethylation of **16** with triethyloxonium fluoroborate occurred at the lactam oxygen to give the imidic ester (7-ethoxy-4*H*-azepine) **23** in good yields. The position of ethylation was confirmed by the derivation of **23** from the cyclobutane imidic esters **22** which have already been prepared by alkylation of **5** with triethyloxonium fluoroborate.[18] The imidate **22**, when treated with tin (IV) chloride in methylene chloride at room temperature, underwent C_1–C_5 bond fission, giving rise to the 4*H*-azepine **23**, though in lower yield.

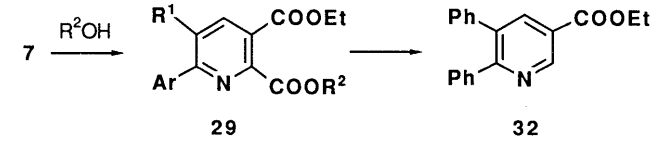
When the methyl ether **21** was heated with DDQ in benzene at 100—120 °C, it was dehydrogenated to give the 3-*O*-methylazatropolone **18** in moderate yields. Dehydrogenation of the 6-H derivative **21e** occurred the most readily (within 3 min) and that of 6-OEt derivative **21d** occurred smoothly (30 min), while that of the 6-Ph **21a**, 6-OAc **21f**, and 6-SPh **21g** derivatives required longer reaction times (1.5 to 2 h) (Table I). These results indicate that the rate of dehydrogenation was greatly affected not only by the electronic nature but also by the bulkiness of the 6-substituents. The methyl ethers **18** were readily purified by silica gel chromatography except for **18e** which suffered hydrolysis during chromatography on silica gel to give the azatropolone **7e**.

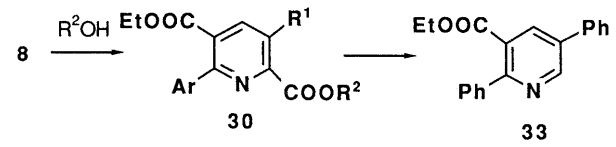
Compounds **18a**, **18d** and **18e** were identical with the 3-*O*-methylazatropolones obtained by the direct methylation of the azatropolones **7a**, **7d** and **7e**. The position of the *O*-methyl group in **19a** and **19d** obtained by the direct methylation of the azatropolones **8a** and **8d** was deduced from the resemblance of their UV spectra to those of **18a** and **18d** (Fig. 2).

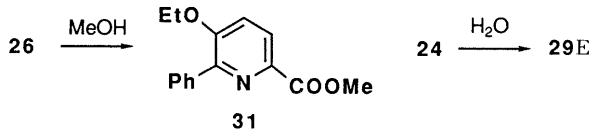
Dehydrogenation of the imidic ester **23** with DDQ took place more readily than that of **21** to yield the corresponding 2-*O*-ethylazatropolone **24** in good yield. The dehydrogenation of the 6-OEt **23d** and 6-H **23e** derivatives was completed within 1—2 min at room temperature. The results are given in Table I. The UV spectra of **24a** and **24d** showed gross similarity to those of the 2-*O*-methyl analogs **20a** and **20d**, although the positions of their substituents on the azatropolone ring are different, thus suggesting the position of the *O*-methyl group in the latter compounds (Fig. 3).

The azatropolone **26** having no ethoxycarbonyl group, which was prepared by decarbethoxylation of **16d** followed by dehydrogenation,[19] on methylation with diazomethane gave a mixture of the 3-*O*-methyl- **27** and 2-*O*-methylazatropolone **28** in a ratio of about 1 : 1. The position of methylation in these products was elucidated by comparison of their UV spectra with those of **19** and **20** (see Figs. 2 and 3).

Rearrangement of Azatropolones to Pyridine-2-carboxylates The remarkable feature of the azatropolones is that they are enormously reactive with protonic solvents. For example, when the azatropolone **8a** was dissolved in methanol, its yellow color faded gradually, indicating that a solvolytic change took place. In fact, on treatment with methanol at room temperature, **7a** and **8a** gave the methyl pyridine-2-carboxylates **29Ma** and **30Ma** in excellent yields, respectively. Treatment of the azatropolone **8d** with methanol at room temperature also caused rearrangement to give the methyl pyridine-2-carboxylate **30Md**. The azatropolones **7d** and **7e** also rearranged to the pyridine-2-carboxylates **29Md** and **29Me**, respectively, although they required forcing conditions [a base catalyst (sodium acetate) and heating under reflux]. The 6-OEt derivative







structures of **29, 30**

M	E	H
R^2 = Me	Et	H

	Ar	R^1
a	Ph	Ph
c	*p*-Br-C_6H_4-	Ph
d	Ph	OEt
e	Ph	H
f	Ph	OAc
g	Ph	SPh
h	Ph	Et

Chart 13

26 which lacked the COOEt group at the C_4 position also required forcing conditions to yield the pyridine-2-carboxylate **31**.[19]

Similarly, treatment of the azatropolones **7a** and **8a** with ethanol and aqueous acetone gave the corresponding ethyl pyridine-2-carboxylates **29Ea** and **30Ea** and pyridine-2-carboxylic acids **29Ha** and **30Ha**, respectively. Methylation of **29Ha** and **30Ha** with diazomethane gave the methyl esters, which were identical with **29Ma** and **30Ma**, respectively.

The structure of the pyridine-2-carboxylate was determined as follows. The carboxylic acids **29Ha** and **30Ha**, when being heated at 120 °C in the presence of silica gel, readily underwent decarboxylation to give the pyridine derivatives **32** and **33**, respectively. The presence of *meta*-coupling between the ring protons in the products (J=2 Hz for **32** and J=2.5 Hz for **33**) supported the structure. Final establishment of the structures was achieved by X-ray crystallographic analyses of the 6-bromophenyl derivatives **29Mc** and **30Mc**.[13b]

The 2-*O*-ethylazatropolones **24a** and **24d—f** also underwent the same ring contraction reaction, when treated with water in the presence of silica gel, giving rise to the ethyl pyridine-2-carboxylates **29Ea** and **29Ed—f**, respectively.

The above ring contraction reaction of azatropolones into pyridine-2-carboxylates can be rationalized by assuming the presence of prototropic tautomers. The azatropolone may exist in three tautomeric forms by prototropic tautomerism, that is, the enol-lactam form (I), the keto-lactim form (II), and the keto-lactam form (III). The positive coloration in the ferric chloride test (greenish yellow) and the results of the reaction with diazomethane, in which methylation occurred at the 2- and 3-oxygen as described above, suggest that they can exist as the tautomers I and II having the phenolic hydroxy group.

TABLE II. Chemical Shifts of Ring Carbons of Azatropolones and Their Analogues

Compound	Chemical shifts of ring carbons (δ)					
	2	3	4	5	6	7
7a	163.4	180.5	136.3	146.0	139.1	142.0
7d[a]	169.4	—	104.5	109.6	—	—
7e	163.8	179.8	135.9	141.7	106.4	145.2
8a	162.9	183.1	137.0	135.5	115.0	143.6
8d	160.0	175.0	140.1	117.0	111.8	151.6
26	161.1	179.0	125.6	139.6	135.3	140.7
18a	164.9	161.5	112.4	131.0	138.7	157.2
18d	165.5	157.5	112.2	111.9	151.7	152.8
27	168.7	157.5	104.4	112.8	135.7	152.2
24a	154.2	171.8	139.4	146.5	141.4	153.2
24d	153.2	171.8	137.4	140.1	145.0	145.6
28	155.6	173.6	131.5	137.4	149.6	141.7
7b	162.1	186.5	134.7	143.3	137.6	142.2
16a	164.2	157.8	109.4	29.4	135.6	139.1
16d	164.0	159.1	120.0	23.7	148.4	133.7

a) The signals were only assigned partially because of the unresolved bands.

On the other hand, the ^{13}C-NMR spectra seem to show a major contribution of the keto-lactam form (III) for azatropolones in $CDCl_3$ solution. The assignment of the ring carbon signals of the azatropolones (Table II) was accomplished by comparison of the spectra of the analogs with those of fixed forms such as the 3-hydroxy-1,5-dihydro-2*H*-azepin-2-one **16** (an enol-lactam form), the 3-*O*-methylazatropolones **18** and **27** (form I), the 2-*O*-alkyl **20** and **24** (form II), and the *N*-methyl **7b** (form III). In the spectrum of **7d** the assignment of signals was only partially achieved because of its very broad unresolved bands. The signal of C-2 appeared in the region of δ 162—170 when the carbon consisted of a lactam carbonyl (**18a**, **18d**, **27**, **16a**, **16d**, and **7b**), while it appeared at δ 153—156 when it consisted of an imidate (**24a**, **24d**, and **28**). On the other hand, the signal of C-3 appeared at δ 157—162 when the carbon was a part of an enol (**18a**, **18d**, **27**, **16a**, and **16d**), and at δ 172—187 when it was a ketone (**24a**, **24d**, **28**, and **7b**). The C-2 signal of azatropolones (**7a**, **7d**, **7e**, **8a**, **8d**, and **26**) appeared in the region of δ 160—170, suggesting that the carbon was a lactam carbonyl, and that of C-3 appeared at δ 175—184, suggesting ketonic character.[20]

The ring contraction reaction should proceed *via* an aziridine intermediate **35** which can be formed by the addition of a nucleophile (R^3OH) to C-2 of the tautomer II or III followed by intramolecular nucleophilic attack of azatropolone nitrogen on the C_3-carbonyl group. The aziridine ring of **35** is then cleaved and the resulting dihydropyridine **36** is aromatized by dehydration to give the pyridine-2-carboxylate. The other possible pathway to the intermediate **35** *via* the 6π-electrocyclic reaction of the tautomer I may be excluded since the 3-*O*-methylazatropolone **18a** remained unchanged after 8 h in boiling methanol.

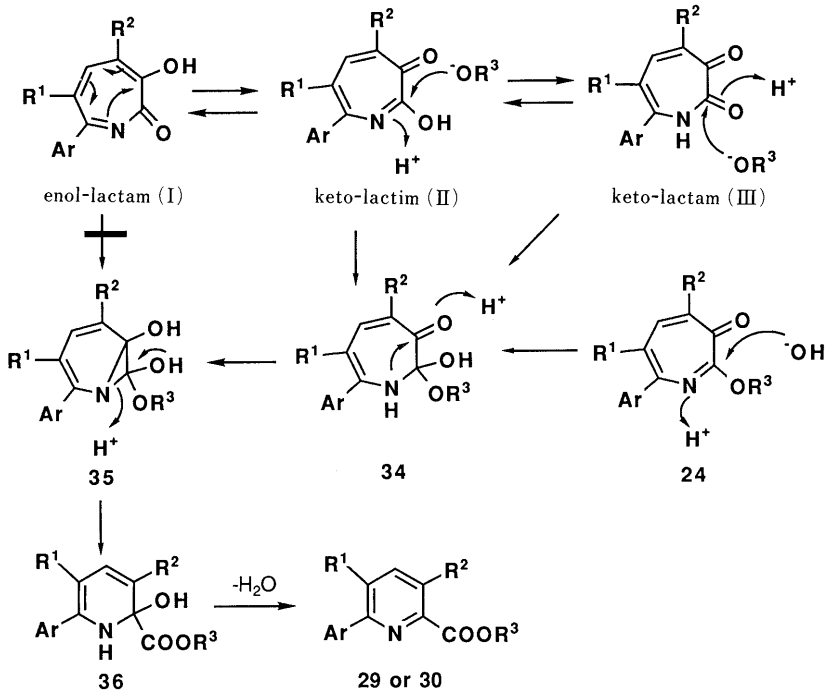


Chart 14

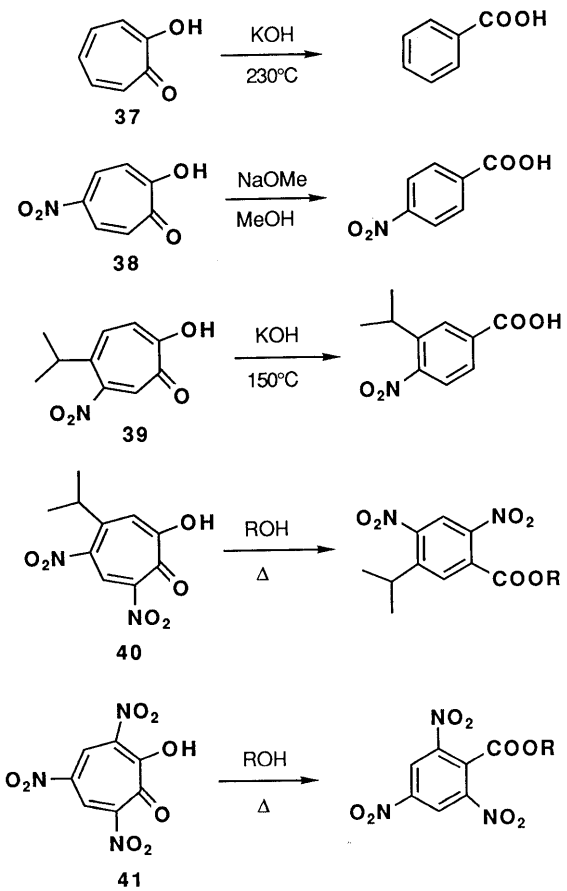


Chart 15

The above results demonstrated that this rearrangement reaction was affected by the substituent on the azatropolone ring and its position. The electron donating OEt group retards the reaction. Removal of the COOEt group (*e.g.* **26**) also retards the reaction.[19] The rearrangement of the azatropolones with a COOEt group at the C_4 position is relatively slow, when compared to that of the 6-COOEt derivatives. This retardation of the reaction may be attributed to the contribution of the enol-lactam form I, which should be stabilized by the 4-COOEt.

The similar benzilic acid type rearrangement reaction is well known in the α-tropolone chemistry,[21] but usually requires more forcing conditions (high temperature and strong base catalyst) as shown in the reactions of **37**,[22] **38**,[22] and **39**,[23] and it is accelerated by the presence of an electron-withdrawing group on the ring.[21] The strongly electron-attracting nitro group increases the electrophilicity of the tropolone nucleus and enhances the reactivity for the solvolytic reaction. The reactivity of the azatropolones **7a** and **8a** is comparable with those of dinitro **40**[24] or trinitro α-tropolone **41**,[25] which readily rearrange to the corresponding benzoates merely on heating in ethanol or methanol without any base.

Experimental

Unless otherwise stated, the following procedures were adopted. Melting points were taken on a Yanagimoto micro hot-stage melting point apparatus and are uncorrected. IR spectra were taken in Nujol mulls for solids and CH_2Cl_2 solution for gums with a Hitachi 260-10 spectrometer and data are given in cm^{-1}. UV spectra were recorded in dioxane solution with a Hitachi 200-10 spectrometer and are given in λ_{max} nm (ε). ^{1}H-NMR (100 MHz) and ^{13}C-NMR (25.0 MHz) spectra were taken in $CDCl_3$ solution with tetramethylsilane as an internal standard on a JEOL FX-100 spectrometer. High resolution mass spectra (MS) were recorded on a JEOL JMS-D300 mass spectrometer. For column chromatography, silica gel (Wako gel C-200) was used. Thin layer chromatography (TLC) was performed on Merck precoated Silica gel 60 F_{254} plates (Merck). Medium pressure liquid chromatography (MPLC) was performed on Kusano CIG prepacked silica gel columns. The photolysis solution was irradiated externally using a 300 W high-pressure mercury lamp (Eikosha Halos PIH 300) with a Pyrex filter.

Photocycloaddition of 1a with Phenylacetylene A solution of **1a** (1.0 g) and phenylacetylene (2.5 mol eq 1.0 g) in DME (300 ml) was irradiated at 0 °C for 45 min. After evaporation of the solvent, the residue was chromatographed. Elution with benzene gave 5-ethoxycarbonyl-3,6-di-

phenyl-2-pyridone **3a** (130 mg, 9%), colorless needles from CH_2Cl_2–Et_2O, mp 222—224 °C. IR: 1695, 1670, 1640. UV (EtOH): 290 (16000), 328 (13200). ^{1}H-NMR: 1.03 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.12 (2H, q, J=7 Hz, $COO\underline{C}H_2CH_3$), 7.5 (10H, m, ArH), 8.22 (1H, s, C_4-H). *Anal.* Calcd for $C_{20}H_{17}NO_3$: C, 75.22; H, 5.37; N, 4.39. MS *m/z*: 319.1209. Found: C, 75.32; H, 5.23; N, 4.34. MS *m/z*: 319.1255. Further elution with CH_2Cl_2–benzene (1 : 1) gave *dl*-(1*R**,5*S**)-5-ethoxycarbonyl-1,7-diphenyl-2-azabicyclo[3.2.0]hept-6-ene-3,4-dione **2a** (570 mg, 40%), pale yellow prisms from CH_2Cl_2–Et_2O, mp 179—183 °C. IR: 3170, 3070, 1750, 1730. UV: 254 (18000), 383 (700), 403 (650). ^{1}H-NMR: 0.79 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.73 (2H, q, J=7 Hz, $COO\underline{C}H_2CH_3$), 6.55 (1H, s, C_6-H), 7.27 (5H, br s, ArH), 7.31 (5H, br s, ArH). *Anal.* Calcd for $C_{21}H_{17}NO_4$: C, 72.61; H, 4.93; N, 4.03. Found: C, 72.65; H, 4.83; N, 4.01. Preparative TLC of the mother liquor (developed with CH_2Cl_2) gave the pyrido-phenanthrene **4** (10 mg, 1%), colorless needles from CH_2Cl_2–Et_2O, mp 228—230 °C. IR 3280, 1730, 1710, 1650, 1600. UV (EtOH): 242 (41000), 305 (9500), 345 (5900). ^{1}H-NMR: 1.43 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.45 (2H, q, J=7 Hz, $COO\underline{C}H_2CH_3$), 7.40 (6H, s, ArH), 7.87 (1H, s, ArH), 8.1—8.3 (2H, m, ArH). *Anal.* Calcd for $C_{20}H_{15}NO_3$: C, 75.69; H, 4.76; N, 4.41. Found: C, 75.56; H, 4.53; N, 4.21.

Photocycloaddition of 1b with Phenylacetylene A solution of **1b** (3.0 g) and phenylacetylene (10 mol eq 9.0 g) in DME (300 ml) was irradiated at 0 °C for 1 h. After evaporation of the solvent, the residue was chromatographed. Elution with benzene gave 5-ethoxycarbonyl-1-methyl-3,6-diphenyl-2-pyridone **3b** (200 mg, 5%), colorless needles from CH_2Cl_2–Et_2O, mp 122—123 °C. IR: 1695, 1650. UV (EtOH): 232 (21100), 276 (13200), 324 (18200). ^{1}H-NMR: 1.00 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.36 (3H, s, NCH_3), 4.05 (2H, q, J=7 Hz, $COO\underline{C}H_2CH_3$), 7.2—7.8 (10H, m, ArH), 8.19 (1H, s, C_4-H). *Anal.* Calcd for $C_{21}H_{19}NO_3$: C, 75.65; H, 5.74; N, 4.20. MS *m/z*: 333. 1356. Found: C, 75.55; H, 5.61; N, 4.27. MS *m/z*: 333.1370. Further elution with CH_2Cl_2–benzene (1 : 1) gave *dl*-(1*R**,5*S**)-5-ethoxycarbonyl-2-methyl-1,7-diphenyl-2-azabicyclo-[3.2.0]hept-6-ene-3,4-dione **2b** (814 mg, 20%), pale yellow gum. IR: 1775, 1725. UV: 252. ^{1}H-NMR: 0.82 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.23 (3H, s, NCH_3), 3.70 (2H, q, J=7 Hz, $COO\underline{C}H_2CH_3$), 6.72 (1H, s, C_6-H), 7.43 (10H, br s, ArH). MS *m/z*: M^+ Calcd for $C_{22}H_{19}NO_4$ 361.1312. Found: 361.1312.

Photocycloaddition of 1c with Phenylacetylene A solution of **1c** (1.0 g) and phenylacetylene (1.0 g) in DME (300 ml) was irradiated at 0 °C for 1 h. After evaporation of the solvent, the residue was chromatographed. Elution with benzene gave 5-ethoxycarbonyl-3-phenyl-6-(*p*-bromophenyl)-2-pyridone **3c** (50 mg, 4%), colorless needles from CH_2Cl_2–Et_2O, mp 127—129 °C. IR: 1725, 1650, 1640. UV (EtOH): 280 (9800), 328 (13800). ^{1}H-NMR: 1.07 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.12 (2H, q, J=7 Hz, $COO\underline{C}H_2CH_3$), 7.3—7.8 (9H, m, ArH), 8.13 (1H, s, C_4-H). MS *m/z*: M^+ Calcd for $C_{20}H_{16}BrNO_3$ 397.0313 and 399.0292. Found: 397.0328 and 399.0285. Further elution with CH_2Cl_2–benzene (1 : 1) gave *dl*-(1*R**,5*S**)-5-ethoxycarbonyl-7-phenyl-1-(*p*-bromophenyl)-2-azabicyclo[3.2.0]hept-6-ene-3,4-dione **2c** (170 mg, 13%), pale yellow plates from CH_2Cl_2–Et_2O, mp 171—176 °C. IR; 3250, 1775, 1740, 1700. UV; 258 (16600), 382 (700), 402 (600). ^{1}H-NMR: 0.83 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.83 (2H, q, J=7 Hz, $COO\underline{C}H_2CH_3$), 6.47 (1H, s, C_6-H), 7.3 (9H, m, ArH). *Anal.* Calcd for $C_{21}H_{16}BrNO_4$: C, 59.17; H, 3.78; N, 3.29. Found: 59.13; H, 3.66; N, 3.55.

Catalytic Hydrogenation of 2a with Pd–C A solution of **2a** (100 mg) in EtOH (20 ml) was hydrogenated over 10% Pd–C (100 mg) at room temperature for 2 h under a pressure of 4.2 atmospheres. After removal of the catalyst by filtration, the filtrate was concentrated *in vacuo*. Chromatography of the residue and elution with CH_2Cl_2–benzene (1 : 1) gave **5a** (70 mg, 69%).

DDQ Oxidation of 6a A solution of the dihydropyridone **6a**[14,17] (20 mg) and DDQ (50 mg) in dioxane (5 ml) was heated in a sealed tube at 120 °C for 20 h. Chromatography of the product and elution with CH_2Cl_2 gave **3a** (10 mg).

Methylation of 3a with Diazomethane A solution of **3a** (20 mg) in CH_2Cl_2 (10 ml) was treated with excess diazomethane at 0 °C overnight. Chromatography of the product and elution with CH_2Cl_2 gave **3b** (15 mg). This was identical with the *N*-methyl pyridone **3b**.

Pyrolysis of Cyclobutenes 2 (General Procedure) A solution of **2** in toluene (5 ml) was heated in a sealed tube at 160 °C for 2 h. After evaporation of the solvent *in vacuo*, the residue was chromatographed over SiO_2 (Mallinckrodt, CC-7). Elution with CH_2Cl_2–benzene (1 : 1) gave the azatropolone **7**.

i) 4-Ethoxycarbonyl-3-hydroxy-6,7-diphenyl-2*H*-azepin-2-one **7a**: **2a** (400 mg) gave **7a** (240 mg, 60%), yellow needles from CH_2Cl_2–Et_2O, mp 151—154 °C. IR: 3200, 1735, 1715, 1690, 1660, 1610, 1600. UV: 227 (19000), 286 (9400), 377 (5400). ^{1}H-NMR: 1.33 (3H, br t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.33 (2H, br q, J=7 Hz, $COO\underline{C}H_2CH_3$), 7.2 (10H, m, ArH), 8.03 (1H, br s, C_5-H). ^{13}C-NMR: 14.0 (q, $COOCH_2\underline{C}H_3$), 62.1 (t, $COO\underline{C}H_2CH_3$), 121.0 (s, Ph), 126—130 (10C, d, Ph), 131.0 (s, Ph), 136.3 (s, C-4 or 6), 139.1 (s, C-4 or 6), 142.0 (s, C-7), 146.0 (d, C-5), 163.4 (s, C-2), 164.7 (s, $\underline{C}OOCH_2CH_3$), 180.5 (s, C-3). *Anal.* Calcd for $C_{21}H_{17}NO_4$: C, 72.61; H, 4.93; N, 4.03. MS *m/z*: 347.1156. Found: C, 72.43; H, 4.76; N, 4.12. MS *m/z*: 347.1038.

ii) 4-Ethoxycarbonyl-1-methyl-6,7-diphenyl-2*H*-azepine-2,3-dione **7b**: **2b** (100 mg) gave **7b** (70 mg, 70%), yellow needles from Et_2O–hexane, mp 130—131 °C. IR: 1730, 1665, 1625, 1610, 1590. UV: 231 (18800), 278 (9400), 357 (5700). ^{1}H-NMR: 1.32 (3H, br t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.02 (3H, s, NCH_3), 4.30 (2H, q, J=7 Hz, $COO\underline{C}H_2CH_3$), 7.1 (10H, m, ArH), 7.92 (1H, s, C_5-H). ^{13}C-NMR: 14.0 (q, $COOCH_2\underline{C}H_3$), 36.0 (q, NMe), 61.9 (t, $COO\underline{C}H_2CH_3$), 126.1 (d, Ph), 127.0 (s, Ph), 128.3 (4C, d, Ph), 128.6 (2C, d, Ph), 127.0 (s, Ph), 134.7 (s, C-4 or 6), 137.6 (s, C-4 or 6), 142.4 (s, C-7), 143.3 (d, C-5), 162.1 (s, C-2), 166.3 (s, $\underline{C}OOCH_2CH_3$), 186.5 (s, C-3). *Anal.* Calcd for $C_{22}H_{19}NO_4$: C, 73.11; H, 5.30; N, 3.88. MS *m/z*: 361.1312. Found: C, 72.96; H, 5.19; N, 4.03. MS *m/z*: 361.1305.

iii) 4-Ethoxycarbonyl-3-hydroxy-6-phenyl-7-(*p*-bromophenyl)-2*H*-azepin-2-one **7c**: **2c** (150 mg) gave **7c** (80 mg, 53%), yellow needles from CH_2Cl_2–Et_2O, mp 155—156 °C. IR: 3300, 1720, 1695, 1625. UV; 235 (20500), 282sh (9900), 373 (9500). ^{1}H-NMR: 1.47 (3H, br t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.4 (2H, m, $COO\underline{C}H_2CH_3$), 7.3 (9H, m, ArH), 7.75 (1H, br s, NH), 8.00 (1H, br s, C_5-H). ^{13}C-NMR: 14.0 (q, $COOCH_2\underline{C}H_3$), 62.1 (t, $COO\underline{C}H_2CH_3$), 121.0 (s, Ph), 126—130 (10C, d, Ph), 131.0 (s, Ph), 136.3 (s, C-4 or 6), 139.1 (s, C-4 or 6), 142.0 (s, C-7), 146.0 (d, C-5), 163.4 (s, C-2), 164.7 (s, $\underline{C}OOCH_2CH_3$), 180.5 (s, C-3). MS *m/z*: M^+ Calcd for $C_{21}H_{16}BrNO_4$ 425.0260 and 427.0240. Found: 427.0223 and 427.0212.

iv) 5-Deuterio-4-ethoxycarbonyl-3-hydroxy-6,7-diphenyl-2*H*-azepin-2-one 7D: **2D**[16] (300 mg) gave 7D (200 mg, 66%), yellow needles from CH_2Cl_2–Et_2O, mp 149—152 °C. IR: 3200, 1720, 1705, 1690, 1650. UV; 227 (18000), 285 (9800), 377 (5500). ^{1}H-NMR: 1.33 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.33 (2H, q, J=7 Hz, $COO\underline{C}H_2CH_3$), 7.2 (10H, m, ArH). MS *m/z*: M^+ Calcd for $C_{21}H_{16}DNO_4$ 348.1218. Found: 348.1207.

Photolysis of the Cyclobutene 2a A solution of **2a** (400 mg) in DME (200 ml) was irradiated at 0 °C for 3 h. After evaporation of the solvent *in vacuo*, the residue was chromatographed over SiO_2 (Mallinckrodt, CC-7). Elution with CH_2Cl_2–benzene (1 : 1) gave 6-ethoxycarbonyl-3-hydroxy-4,7-diphenyl-2*H*-azepin-2-one **8a** (45 mg, 11%), yellow needles from CH_2Cl_2–Et_2O, mp 191—194 °C. IR: 3180, 1700, 1650, 1590. UV: 230 (18600), 328 (12200), 365 (11000). ^{1}H-NMR: 0.83 (3H, t, J=8 Hz, $COOCH_2C\underline{H}_3$), 3.88 (2H, q, J=8 Hz, $COO\underline{C}H_2CH_3$), 7.47 (10H, m, ArH), 7.68 (1H, s, C_5-H). ^{13}C-NMR: 13.3 (q, $COOCH_2\underline{C}H_3$), 61.6 (t, $COO\underline{C}H_2CH_3$), 114.97 (s, C-6), 127.9, 128.3, 128.5, 128.7, 128.9, 130.4 (s and d, Ph), 135.5 (d, C-5), 137.0 (s, C-4), 143.6 (s, C-7), 169.2 (s, C-2), 167.8 (s, $\underline{C}OOCH_2CH_3$), 183.1 (s, C-3). MS *m/z*: M^+ Calcd for $C_{21}H_{17}NO_4$: 347.1156. Found: 347.1065. Futher elution with CH_2Cl_2 gave **3a** (37 mg, 10%).

Photocycloaddition of 1a with Ethoxyacetylene A solution of **1a** (3.0 g) and ethoxyacetylene (2.15 g) in DME (300 ml) was irradiated at 0 °C for 45 min. After evaporation of the solvent, the residue was chromatographed over SiO_2 (Mallinkrodt, CC-7). Elution with benzene–CH_2Cl_2 (1 : 1) gave 3-ethoxy-5-ethoxycarbonyl-6-phenyl-2-pyridone **3d** (950 mg, 27%), colorless needles from CH_2Cl_2–Et_2O, mp 177—179 °C. IR: 1700, 1650. UV (EtOH): 290 (16700). ^{1}H-NMR: 0.97 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.50 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 4.07 (2H, q, J=7 Hz, $COO\underline{C}H_2CH_3$), 4.10 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 7.27 (1H, s, C_4-H), 7.43 (5H, s, ArH). *Anal.* Calcd for $C_{16}H_{17}NO_4$: C, 66.88; H, 5.96; N, 4.88. MS *m/z*: 287.1156. Found: C, 66.66; H, 5.96; N, 4.91. MS *m/z*: 287.1148. Further elution with CH_2Cl_2 gave 4-ethoxy-6-ethoxycarbonyl-3-hydroxy-7-phenyl-2*H*-azepin-2-one **8d** (860 mg, 22%), yellow needles from CH_2Cl_2–Et_2O, mp 179—181 °C. IR: 1715, 1690, 1670. UV: 265sh (11800), 312 (8500), 380 (6200). ^{1}H-NMR: 0.78 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.47 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 3.85 (2H, q, J=7 Hz, $COO\underline{C}H_2CH_3$), 4.07 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 6.98 (1H, s, C_5-H), 7.37 (5H, m, ArH). ^{13}C-NMR: 13.0 (q, $COOCH_2\underline{C}H_3$), 14.5 (q, $OCH_2\underline{C}H_3$), 61.5 (t, $COO\underline{C}H_2CH_3$), 65.3 (t, $O\underline{C}H_2CH_3$), 111.8 (s, C-6), 117.5 (d, C-5), 127.3 (d, Ph), 127.9 (d, Ph), 128.6 (d, Ph), 129.2 (d, Ph), 130.6 (d, Ph), 137.1 (s, Ph), 140.9 (s, C-7), 151.6 (s, C-4), 160.0 (s, C-2), 168.0 (s, $\underline{C}OOCH_2CH_3$), 175.0 (s, C-3). *Anal.* Calcd for $C_{17}H_{17}NO_5$: C, 64.75; H, 5.43; N, 4.44. MS *m/z*: 315.1105. Found: C, 64.49; H, 5.27; N, 4.22. MS *m/z*: 315.1058.

Preparation of 1,5-Dihydro-2*H*-azepin-2-ones 16 (General Procedure) A

solution of **5**[14] (300 mg) and DBU (600 mg) in benzene (30 ml) was treated at room temperature overnight (**5a, i**) or refluxed for 2 h (**5d, f, g, h**). The reaction mixture was diluted with CH_2Cl_2, washed with 5% HCl and water, dried over Na_2SO_4 and evaporated. Chromatography of the residue and elution with CH_2Cl_2 gave **16** which was crystallized from CH_2Cl_2–Et_2O.

i) 4-Ethoxycarbonyl-3-hydroxy-6,7-diphenyl-1,5-dihydro-2*H*-azepin-2-one **16a**: Yield 86% from the 7-*exo*-Ph isomer (**5a**) and 80% from the 7-*endo*-Ph isomer (**5a**). Pale yellow needles, mp 226—236 °C. IR: 3200, 1670, 1600. UV: 226 (19200), 269 (17600). ^{1}H-NMR: 1.03 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.43 (2H, s, C_5-H), 4.13 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.12 (5H, s, ArH), 7.17 (5H, s, ArH). ^{13}C-NMR: 13.7 (q, $COOCH_2\underline{C}H_3$), 29.36 (t, C-5), 61.6 (t, $COO\underline{C}H_2CH_3$), 109.4 (s, C-4), 127.0 (d, Ph), 128.1 (2C, d, Ph), 128.4 (2C, d, Ph), 128.6 (s, Ph), 128.8 (d, Ph), 129.3 (2C, d, Ph), 129.9 (2C, d, Ph), 132.5 (s, Ph), 135.6 (s, C-6), 139.1 (s, C-7), 157.8 (s, C-3), 164.2 (s, C-2), 170.4 (s, $\underline{C}OOCH_2CH_3$). *Anal.* Calcd for $C_{21}H_{19}NO_4$: C, 72.19; H, 5.48; N, 4.01. MS *m/z*: 349.1313. Found: C, 71.90; H, 5.37; N, 4.02. MS *m/z*: 349.1313.

ii) 6-Ethoxy-4-ethoxycarbonyl-3-hydroxy-7-phenyl-1,5-dihydro-2*H*-azepin-2-one **16d**: Yield 70% from the 7-*endo*-OEt isomer (**5d**). Yellow needles, mp 173—178 °C. IR: 3200, 1620. UV: 220 (13600), 262 (17400). ^{1}H-NMR: 1.20 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 1.37 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.27 (2H, s, C_5-H), 3.85 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 4.37 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.4 (5H, m, ArH). ^{13}C-NMR: 14.0 (q, $COOCH_2\underline{C}H_3$), 15.1 (q, $OCH_2\underline{C}H_3$), 23.7 (t, C-5), 61.8 (t, $COO\underline{C}H_2CH_3$), 66.1 (t, $O\underline{C}H_2CH_3$), 108.1 (s, C-4), 119.9 (s, C-7), 127.8 (d, Ph), 127.9 (2C, d, Ph), 128.1 (2C, d, Ph), 133.7 (s, Ph), 148.4 (s, C-6), 159.1 (s, C-3), 164.0 (s, C-2), 170.0 (s, $\underline{C}OOCH_2CH_3$). *Anal.* Calcd for $C_{17}H_{19}NO_5$: C, 64.34; H, 6.04; N, 4.41. MS *m/z*: 317.1262. Found: C, 64.06; H, 5.97; N, 4.38. MS *m/z*: 317.1219.

iii) 6-Acetoxy-4-ethoxycarbonyl-3-hydroxy-7-phenyl-1,5-dihydro-2*H*-azepin-2-one **16f**: Yield 71% from the 7-*endo*-OAc isomer (**5f**). Colorless needles, mp 192—194 °C. IR: 3200, 1765, 1680, 1660, 1610. UV: 220 (14000), 258 (15400). ^{1}H-NMR: 1.33 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 2.05 (3H, s, OAc), 3.27 (2H, s, C_5-H), 4.33 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.38 (5H, s, ArH). *Anal.* Calcd for $C_{17}H_{17}NO_6$: C, 61.63; H, 5.17; N, 4.23. MS *m/z*: 331.1055. Found: C, 61.56; H, 5.09; N, 3.93. MS *m/z*: 331.1055.

iv) 4-Ethoxycarbonyl-3-hydroxy-7-phenyl-6-phenylthio-1,5-dihydro-2*H*-azepin-2-one **16g**: Yield 92% from the 7-*exo*-SPh isomer (**5g**). Yellow needles, mp 178—180 °C. IR: 3200, 3050, 1670, 1600. UV: 220 (20300), 263 (18200). ^{1}H-NMR: 1.17 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.33 (2H, s, C_5-H), 4.07 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.33 (5H, s, ArH), 7.45 (5H, s, ArH). *Anal.* Calcd for $C_{21}H_{19}NO_4S$: C, 66.12; H, 5.02; N, 3.67. MS *m/z*: 381.1050. Found: C, 65.92; H, 5.03; N, 3.48. MS *m/z*: 381.1037.

v) 4-Ethoxycarbonyl-6-ethyl-3-hydroxy-7-phenyl-1,5-dihydro-2*H*-azepin-2-one **16h**: Yield 63% from the 7-*exo*-Et isomer (**5h**) and 60% from the 7-*endo*-Et isomer (**5h**). Yellow needles, mp 140—145 °C. IR: 3200, 1665, 1600. UV: 227 (13000), 263 (13500). ^{1}H-NMR: 1.04 (3H, t, J=7 Hz, $CH_2C\underline{H}_3$), 1.32 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 2.12 (2H, q, J=7 Hz, $C\underline{H}_2CH_3$), 2.98 (2H, s, C_5-H), 4.30 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.28 (5H, s, ArH). MS *m/z*: M$^+$ Calcd for $C_{17}H_{19}NO_4$ 301.1313. Found: 301.1292.

vi) 4-Ethoxycarbonyl-3-hydroxy-7-phenyl-6-vinyl-1,5-dihydro-2*H*-azepin-2-one **16i**: Yield 80% from the 7-*exo*-vinyl isomer (**5i**) and 70% from the 7-*endo*-vinyl isomer (**5i**). Yellow needles, mp 162—167 °C. IR: 3200, 1680, 1660, 1610. UV: 233 (19900), 263 (19600). ^{1}H-NMR: 1.37 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.27 (2H, s, C_5-H), 4.33 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 5.15 (1H, d, J=10 Hz, $CH{=}C\underline{H}_2$), 5.60 (1H, d, J=17 Hz, $CH{=}C\underline{H}_2$), 6.00 (1H, dd, J=10, 17 Hz, $C\underline{H}{=}CH_2$), 7.38 (5H, s, ArH). MS *m/z*: M$^+$ Calcd for $C_{17}H_{17}NO_4$ 299.1158. Found: 299.1160.

Preparation of 16e A solution of **5g** (80 mg) in EtOH (10 ml) was treated with Raney Ni (W_2) (1 ml) under vigorous stirring at room temperature for 6 h. After removal of the catalyst by filtration, the filtrate was concentrated to dryness. Chromatography of the residue and elution with CH_2Cl_2 gave 4-ethoxycarbonyl-3-hydroxy-7-phenyl-1,5-dihydro-2*H*-azepin-2-one **16e** (30 mg, 53%), colorless needles from CH_2Cl_2, mp 194—197 °C. IR: 3200, 1680, 1660, 1600. UV: 220 (13000), 263 (13500). ^{1}H-NMR: 1.37 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.03 (2H, d, J=8 Hz, C_5-H), 4.33 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 5.95 (1H, t, J=8 Hz, C_6-H), 7.40 (5H, s, ArH). MS *m/z*: M$^+$ Calcd for $C_{15}H_{15}NO_4$ 273.1002. Found: 273.1147.

Methylation of 16 with Diazomethane (General Procedure) A solution of **16** (200 mg) in CH_2Cl_2 (10 ml) was treated with large excess of diazomethane Et_2O solution at −10 °C overnight. After evaporation of the solvent *in vacuo*, chromatography of the residue and elution with CH_2Cl_2 gave **21**, which was crystallized from CH_2Cl_2–Et_2O.

i) 4-Ethoxycarbonyl-3-methoxy-6,7-diphenyl-1,5-dihydro-2*H*-azepin-2-one **21a**: Yield 85%. Pale yellow needles, mp 178—179 °C. IR: 1700, 1660, 1620. UV: 228 (18800), 300sh (10000). ^{1}H-NMR: 1.05 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.42 (2H, s, C_5-H), 3.90 (3H, s, OCH_3), 4.08 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.17 (5H, s, ArH), 7.17 (5H, s, ArH). MS *m/z*: M$^+$ Calcd for $C_{21}H_{19}NO_4$ 363.1469. Found: 363.1318.

ii) 6-Ethoxy-4-ethoxycarbonyl-3-methoxy-7-phenyl-1,5-dihydro-2*H*-azepin-2-one **21d**: Yield 80%. Pale yellow prisms, mp 97—99 °C. IR: 1690, 1645, 1605. UV: 222 (13300), 252 (12200). ^{1}H-NMR: 1.25 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 1.36 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.28 (2H, s, C_5-H), 3.86 (3H, s, OCH_3), 3.90 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 4.32 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.45 (5H, m, ArH). MS *m/z*: M$^+$ Calcd for $C_{18}H_{21}NO_5$ 331.1419. Found: 331.1429.

iii) 4-Ethoxycarbonyl-3-methoxy-7-phenyl-1,5-dihydro-2*H*-azepin-2-one **21e**: Yield 70%. Colorless prisms, mp 130—131 °C. IR: 1690, 1660sh, 1640, 1620. UV: 222 (14000), 249 (12800). ^{1}H-NMR: 1.32 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.00 (2H, d, J=8 Hz, C_5-H), 3.75 (3H, s, OCH_3), 4.37 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 5.90 (1H, t, J=8 Hz, C_6-H), 7.35 (5H, m, ArH). MS *m/z*: M$^+$ Calcd for $C_{16}H_{17}NO_4$ 287.1156. Found: 287.1181.

iv) 6-Acetoxy-4-ethoxycarbonyl-3-methoxy-7-phenyl-1,5-dihydro-2*H*-azepin-2-one **21f**: Yield 78% Colorless needles, mp 136—138 °C. IR: 1765, 1700, 1660, 1625. UV: 220 (14000), 253 (13400). ^{1}H-NMR: 1.34 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 2.08 (3H, s, OAc), 3.32 (2H, s, C_5-H), 3.76 (3H, s, OCH_3), 4.29 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.38 (5H, s, ArH). MS *m/z*: M$^+$ Calcd for $C_{18}H_{19}NO_6$ 345.1210. Found: 345.1202.

v) 4-Ethoxycarbonyl-3-methoxy-7-phenyl-6-phenylthio-1,5-dihydro-2*H*-azepin-2-one **21g**: Yield 84%. Yellow prisms, mp 136—141 °C. IR: 1710, 1660, 1630, 1605. UV: 220 (21600), 260 (15400). 315sh (7500). ^{1}H-NMR: 1.22 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.20 (2H, s, C_5-H), 3.78 (3H, s, OCH_3), 4.10 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.23 (5H, s, ArH), 7.35 (5H, br s, ArH). *Anal.* Calcd for $C_{22}H_{21}NO_4S$: C, 66.81; H, 5.35; N, 3.54. MS *m/z*: 395.1190. Found: C, 66.60; H, 5.35; N, 3.24. MS *m/z*: 395.1220.

vi) 4-Ethoxycarbonyl-6-ethyl-3-methoxy-7-phenyl-1,5-dihydro-2*H*-azepin-2-one **21h**: Yield 84%. Colorless prisms, mp 116—118 °C. IR: 3160, 3050, 1700, 1660, 1620. UV: 222 (13300), 252 (12200). ^{1}H-NMR: 1.08 (3H, t, J=7 Hz, $CH_2C\underline{H}_3$), 1.33 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 2.20 (2H, q, J=7 Hz, $C\underline{H}_2CH_3$), 2.98 (2H, s, C_5-H), 3.78 (3H, s, OCH_3), 4.32 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.35 (5H, br s, ArH). *Anal.* Calcd for $C_{18}H_{21}NO_4$: C, 68.55; H, 6.71; N, 4.44. MS *m/z*: 315.1469. Found: C, 68.62; H, 6.73; N, 4.50. MS *m/z*: 315.1434.

Preparation of 7-Ethoxy-6-hydroxy-4*H*-azepine 23 (General Procedure) Method A: A solution of **16** (150 mg) in CH_2Cl_2 (20 ml) was treated with an excess of Et_3OBF_4 at room temperature overnight. The mixture was diluted with CH_2Cl_2, washed with 5% $NaHCO_3$ and water, dried over Na_2SO_4, and concentrated. Chromatography of the residue over SiO_2 (Mallinckrodt, CC-7) and elution with benzene gave **23**. The product was purified by recrystallization from Et_2O–hexane.

Method B: A solution of **22** (100 mg) and $SnCl_4$ (1.5 mol eq) in CH_2Cl_2 (10 ml) was stirred at room temperature for 5 h. The mixture was passed through a short column of SiO_2 and the eluate was concentrated. Chromatography of the residue over SiO_2 (Mallinkrodt, CC-7) and elution with benzene gave **23**.

i) 7-Ethoxy-5-ethoxycarbonyl-6-hydroxy-2,3-diphenyl-4*H*-azepine **23a**: Yield 94% (method A) and 69% (method B). Pale yellow prisms, mp 114—115 °C. IR: 1660, 1620, 1600. UV: 234 (20600), 268 (17800), 345sh (2100). ^{1}H-NMR: 1.37 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.40 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 3.03 (2H, s, C_4-H), 4.38 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 4.40 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 7.17 (10H, m, ArH). MS *m/z*: M$^+$ Calcd for $C_{23}H_{23}NO_4$ 377.1625. Found: 377.1535.

ii) 3,7-Diethoxy-5-ethoxycarbonyl-6-hydroxy-2-phenyl-4*H*-azepine **23d**: Yield 65% (method A) and 12% (method B). Yellow gum. IR: 1730, 1660, 1620. UV: 255 (10700). ^{1}H-NMR: 1.21 (3H, t, J=7 Hz, OCH_2CH_3), 1.33 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.40 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 2.90 (2H, s, C_4-H), 3.92 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 4.30 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 4.38 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 7.1—7.4 (5H, m, ArH). MS *m/z*: M$^+$ Calcd for $C_{19}H_{23}NO_5$ 345.1572. Found: 345.1482.

iii) 7-Ethoxy-5-ethoxycarbonyl-6-hydroxy-2-phenyl-4*H*-azepine **23e**: Yield 50% (method A). Colorless gum. IR: 1658, 1620. UV: 223 (13600), 258 (17300), 335sh (1300). ^{1}H-NMR: 1.35 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.43 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 2.68 (2H, d, J=7 Hz, C_4-H), 4.30 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 4.47 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 5.85 (1H,

t, J=7 Hz, C_3-H), 7.1—7.4 (3H, m, ArH), 7.4—7.7 (2H, m, ArH). MS m/z: M^+ Calcd for $C_{17}H_{19}NO_4$ 301.1312. Found: 301.1310.

iv) 3-Acetoxy-7-ethoxy-5-ethoxycarbonyl-6-hydroxy-2-phenyl-4*H*-azepine **23f**: Yield 82% (method A) and 43% (method B). Pale yellow prisms, mp 73—75 °C. IR: 1765, 1660, 1620. UV: 228sh (12000), 253 (16500), 335sh (1500). ^{1}H-NMR: 1.33 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.40 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 2.07 (3H, s, OAc), 2.97 (2H, s, C_4-H), 4.32 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 4.37 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 7.1—7.6 (5H, m, ArH). MS m/z: M^+ Calcd for $C_{19}H_{21}NO_6$ 359.1369. Found: 359.1394.

DDQ Oxidation of 3-Hydroxy-1,5-dihydro-2*H*-azepin-2-one 16 (General Procedure) A solution of **16** (100 mg) and DDQ (1.3 mol eq) in benzene (5 ml) was heated at 100 °C in a sealed tube (5 min for **16e**, 10 min for **16i**, 25 min for **16d**, and 45 min for **16a** and **16f—h**). In the cases of **16d** and **16e**, the reaction mixture was passed through a column of SiO_2 (Mallinckrodt, CC-7) to give the azatropolone **7** (65% from **16d** and 50% from **16e**). In the cases of **16a** and **16f—h**, the reaction mixture was diluted with MeOH (20 ml). NaOAc (5 mg) was added to the mixture and the whole was refluxed for 3 h. After evaporation of the solvent the residue was chromatographed. Elution with benzene gave the methyl pyridine-2-carboxylate **29M** (2% from **16a**, 5% from **16f**, 5% from **16g**, and 17% from **16h**). Further elution with CH_2Cl_2 gave the starting material **16** (**16a**: 30%, **16f**: 35%, **16g**: 40%, **16h**: 17%). In the case of **16i** the reaction mixture was diluted with CH_2Cl_2 (50 ml), washed with water, dried over Na_2SO_4, and concentrated. Chromatography of the residue and elution with CH_2Cl_2 gave the DDQ adduct **17** (60%).

i) 6-Ethoxy-4-ethoxycarbonyl-3-hydroxy-7-phenyl-2*H*-azepine-2-one **7d**: Yellow needles from CH_2Cl_2–Et_2O, mp 92—95 °C. IR: 1720, 1660. UV: 251sh (7900), 320 (6000), 385 (7900). ^{1}H-NMR: 1.30 (3H, br t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.42 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 3.83 (2H, m, $OC\underline{H}_2CH_3$), 4.41 (2H, br q, J=7 Hz, $COOC\underline{H}_2CH_3$), 6.78 (1H, br s, C_5-H), 7.45 (3H, m, ArH), 7.8 (2H, m, ArH). The ^{13}C-NMR gave unresolved bands which could not be assigned. *Anal.* Calcd for $C_{17}H_{17}NO_5$: C, 64.75; H, 5.43; N, 4.44. MS m/z: 315.1105. Found: C, 64.85; H, 5.40; N, 4.28. MS m/z: 315.1075.

ii) 4-Ethoxycarbonyl-3-hydroxy-7-phenyl-2*H*-azepin-2-one **7e**: Yellow needles from CH_2Cl_2–Et_2O, mp 187—189 °C. IR: 1725, 1675, 1640, 1610. UV: 241 (10800), 310sh (6700), 371 (12800). ^{1}H-NMR: 1.30 (3H, br t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.30 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 6.25 (1H, d, J=9 Hz, C_6-H), 7.5 (5H, m, ArH), 7.85 (1H, d, J=9 Hz, C_5-H). ^{13}C-NMR: 13.9 (q, $COOCH_2\underline{C}H_3$), 61.8 (t, $COO\underline{C}H_2CH_3$), 106.4 (d, C-5), 126.9 (2C, d, Ph), 129.5 (2C, d, Ph), 131.0 (d, Ph), 131.3 (s, Ph), 135.9 (s, C-4), 141.7 (d, C-6), 145.2 (s, C-7), 163.8 (s, C-2), 165.1 (s, $\underline{C}OOCH_2CH_3$), 179.8 (s, C-3). MS m/z: M^+ Calcd for $C_{15}H_{13}NO_4$ 271.0845. Found: 271.0861.

iii) 3-Ethoxycarbonyl-2-methoxycarbonyl-5,6-diphenylpyridine **29Ma**: Colorless prisms from Et_2O–hexane, mp 103—105 °C. IR: 1750, 1725, 1590. UV (EtOH): 247 (17200), 300sh (9900). ^{1}H-NMR: 1.38 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.03 (3H, s, $COOCH_3$), 4.43 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.30 (10H, m, ArH), 8.27 (1H, s, C_4-H). *Anal.* Calcd for $C_{22}H_{19}NO_4$: C, 73.11; H, 5.30; N, 3.88. MS m/z: 361.1312. Found: C, 72.95; H, 5.17; N, 3.99. MS m/z: 361.1219.

iv) 5-Acetoxy-3-ethoxycarbonyl-2-methoxycarbonyl-6-phenylpyridine **29Mf**: Colorless prisms from Et_2O–hexane, mp 62—64 °C. IR: 1760, 1740, 1720, 1590. UV (EtOH): 263 (11100), 293 (12600). ^{1}H-NMR: 1.37 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 2.20 (3H, s, OAc), 3.97 (3H, s, $COOCH_3$), 4.37 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.27 (5H, m, ArH), 7.92 (1H, s, C_4-H), MS m/z: M^+ Calcd for $C_{18}H_{17}NO_6$ 343.1054. Found: 343.1053.

v) 3-Ethoxycarbonyl-2-methoxycarbonyl-6-phenyl-5-phenylthiopyridine **29Mg**: Colorless prisms from Et_2O–hexane, mp 78—82 °C. IR: 1745, 1740, 1720, 1590. UV (EtOH): 260 (16300), 284 (15300). ^{1}H-NMR: 1.27 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.95 (3H, s, $COOCH_3$), 4.30 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.45 (10H, m, ArH), 7.70 (1H, s, C_4-H). MS m/z: M^+ Calcd for $C_{22}H_{19}NO_4S$ 393.1035. Found: 393.1085.

vi) 5-Ethyl-3-ethoxycarbonyl-2-methoxycarbonyl-6-phenylpyridine **29Mh**: Colorless prisms from Et_2O–hexane, mp 88—89 °C. IR: 1740, 1720, 1590. ^{1}H-NMR: 1.17 (3H, t, J=8 Hz, $CH_2C\underline{H}_3$), 1.38 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 2.77 (2H, t, J=8 Hz, $C\underline{H}_2CH_3$), 3.97 (3H, s, $COOCH_3$), 4.42 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.47 (5H, s, ArH), 8.13 (1H, s, C_4-H). MS m/z: M^+ Calcd for $C_{18}H_{19}NO_4$ 313.1313. Found: 313.1310.

vii) DDQ adduct **17**: Colorless needles from CH_2Cl_2–Et_2O, mp 163—165 °C (dec.). IR: 3350, 1710, 1660. UV (EtOH): 219 (14700), 262 (13000). ^{1}H-NMR: 1.18 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.4 (3H, m), 4.15 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 5.95 (1H, m), 6.90 (1H, m), 7.4 (5H, m, ArH), 7.8 (1H, s). ^{13}C-NMR: 14.8 (q, $COOCH_2\underline{C}H_3$), 30.3 (t), 32.6 (t), 54.8 (s), 63.5 (t, $COO\underline{C}H_2CH_3$), 64.5 (s), 69.5 (s), 96.1 (s), 106.1 (2C, s), 112.2 (s), 114.9 (s), 124.1 (d), 124.6 (d), 126.2 (d), 130.2 (d), 130.8 (d), 131.4 (s), 131.6 (d), 141.7 (s), 158.8 (s), 159.2 (s), 164.9 (s), 172.3 (s), 177.1 (s). MS m/z: M^+ Calcd for $C_{25}H_{17}Cl_2N_3O_6$ 525.0519 and 527.0545. Found: 525.0522 and 527.0515.

DDQ Oxidation of 3-Methoxy-1,5-dihydro-2*H*-azepin-2-one 21: Synthesis of 3-Methoxy-azepin-2-one 18 (General Procedure) A solution of **21** (100 mg) and DDQ (1.3 mol eq) in benzene (5 ml) was heated in a sealed tube. Chromatography of the reaction mixture and elution with benzene–CH_2Cl_2 (1 : 1) gave the 3-methoxy-2*H*-azepin-2-one **18**. The crystalline products were recrystallized from CH_2Cl_2–Et_2O. The reaction conditions and yields are given in Table I. In the case of **21e**, the product **18e** was hydrolyzed during the SiO_2 chromatographic purification procedure to give the 3-hydroxy-2*H*-azepin-2-one **7e**.

i) 4-Ethoxycarbonyl-3-methoxy-6,7-diphenyl-2*H*-azepin-2-one **18a**: Yellow needles, mp 131—133 °C. IR: 1735, 1700, 1620, 1600. UV: 253 (17000), 286 (9400), 300 (12300). ^{1}H-NMR: 1.42 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.17 (3H, s, OCH_3), 4.42 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.3 (8H, m, ArH), 7.6 (2H, m, ArH), 7.92 (1H, s, C_5-H). ^{13}C-NMR: 14.3 (q, $COOCH_2\underline{C}H_3$), 59.5 (q, OCH_3), 61.5 (t, $COO\underline{C}H_2CH_3$), 112.4 (s, C-4), 127.8 (d, Ph), 128.1 (2C, d, Ph), 130.5 (d, Ph), 131.0 (d, Ph), 134.8 (d, C-5), 136.1 (s, Ph), 136.8 (s, Ph), 138.7 (s, C-6), 157.2 (s, C-7), 161.5 (s, C-3), 164.9 (s, C-2), 167.4 (s, $\underline{C}OOCH_2CH_3$). *Anal.* Calcd for $C_{22}H_{19}NO_4$: C, 73.11; H, 5.30; N, 3.88. MS m/z: 361.1314. Found: C, 73.31; H, 5.23; N, 3.88. MS m/z: 361.1214.

ii) 6-Ethoxy-4-ethoxycarbonyl-3-methoxy-7-phenyl-2*H*-azepin-2-one **18d**: Yellow prisms, mp 72—73 °C. IR: 1720, 1680, 1615, 1600. UV: 260 (13500), 360 (3400). ^{1}H-NMR; 1.27 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 1.33 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.92 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 3.97 (3H, s, OCH_3), 4.30 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 6.75 (1H, s, C_5-H), 7.4 (3H, m, ArH), 7.8 (2H, m, ArH). ^{13}C-NMR: 14.0 (q, $COOCH_2\underline{C}H_3$), 14.2 (q, $OCH_2\underline{C}H_3$), 59.1 (q, OCH_3), 61.4 (t, $COO\underline{C}H_2CH_3$), 65.1 (t, $O\underline{C}H_2CH_3$), 111.9 (d, C-5), 112.2 (s, C-4), 128.0 (d, Ph), 128.2 (d, Ph), 130.0 (d, Ph), 130.2 (d, Ph), 131.6 (d, Ph), 134.4 (s, Ph), 157.5 (s, C-3), 165.4 (s, C-2), 165.4 (s, $\underline{C}OOCH_2CH_3$). *Anal.* Calcd for $C_{18}H_{19}NO_5$: C, 65.64; H, 5.82; N, 4.25. MS m/z: 329.1263. Found: C, 65.65; H, 5.82; N, 4.34. MS m/z: 329.1290.

iii) 6-Acetoxy-4-ethoxycarbonyl-3-methoxy-7-phenyl-2*H*-azepin-2-one **18f**: Yellow gum. IR: 1780, 1740, 1700, 1635, 1600. UV: 263 (9900), 287 (9000), 355sh (4000). ^{1}H-NMR: 1.37 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.93 (3H, s, OAc), 4.07 (3H, s, OCH_3), 4.33 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.4 (4H, m, C_5-H and ArH), 7.7 (2H, m, ArH). MS m/z: M^+ Calcd for $C_{18}H_{17}NO_6$ 343.1054. Found: 343.1034.

iv) 4-Ethoxycarbonyl-3-methoxy-7-phenyl-6-phenylthio-2*H*-azepin-2-one **18g**: Yellow gum. IR: 1730, 1700, 1605. UV: 250 (18000), 340 (6400). ^{1}H-NMR: 1.39 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.12 (3H, s, OCH_3), 4.37 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.0—7.7 (10H, m, ArH), 7.89 (1H, s, C_5-H). MS m/z: M^+ Calcd for $C_{22}H_{19}NO_4S$ 393.1033. Found: 393.0978.

v) 4-Ethoxycarbonyl-6-ethyl-3-methoxy-7-phenyl-2*H*-azepin-2-one **18h**: Yellow gum. IR: 1720, 1680, 1605. UV: 220 (12300), 262 (12800), 345sh (3300). ^{1}H-NMR: 0.96 (3H, t, J=8 Hz, $CH_2C\underline{H}_3$), 1.38 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 2.57 (2H, q, J=8 Hz, $C\underline{H}_2CH_3$), 4.07 (3H, s, OCH_3), 4.38 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.5 (6H, m, C_5-H and ArH). MS m/z: M^+ Calcd for $C_{18}H_{19}NO_4$ 313.1315. Found: 313.1331.

DDQ Oxidation of 7-Ethoxy-6-hydroxy-4*H*-azepine 23: Synthesis of 2-Ethoxy-3*H*-azepin-3-ones 24 (General Procedure) A solution of **23** (100 mg) and DDQ (1.3 mol eq) in benzene (5 ml) was heated in a sealed tube. The reaction mixture was passed through a short column of SiO_2 (Mallinkrodt, CC-7) to give the 2-ethoxy-3*H*-azepin-3-one **24**. The reaction conditions and yields were accumulated in Table I.

i) 2-Ethoxy-4-ethoxycarbonyl-6,7-diphenyl-3*H*-azepin-3-one **24a**: Yellow gum. IR: 1720, 1655, 1620. UV: 240 (21200), 349 (9800), 398 (8600). ^{1}H-NMR: 1.37 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.50 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 4.40 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 4.55 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 7.13—7.53 (10H, m, ArH), 8.17 (1H, s, C_5-H). ^{13}C-NMR: 13.9 (q, $COOCH_2\underline{C}H_3$), 1.42 (q, $OCH_2\underline{C}H_3$), 61.8 (t, $COO\underline{C}H_2CH_3$), 64.1 (t, $O\underline{C}H_2CH_3$), 126.0 (d, Ph), 126.8 (d, Ph), 127.2 (2C, d, Ph), 127.8 (2C, d and s, Ph), 129.2 (d, Ph), 130.6 (3C, d and s, Ph), 139.4 (s, C-4), 141.4 (s, C-6), 146.5 (d, C-5), 153.2 (s, C-7), 154.2 (s, C-2), 165.4 (s, $\underline{C}OOCH_2CH_3$), 171.8 (s, C-3). MS m/z: M^+ Calcd for $C_{23}H_{21}NO_4$ 375.1469. Found: 375.1456.

ii) 2,6-Diethoxy-4-ethoxycarbonyl-7-phenyl-3*H*-azepin-3-one **24d**: Yellow gum. IR: 1723, 1660sh, 1640. UV: 247sh (10600), 355 (5100), 395

(5300). ^{1}H-NMR: 1.22 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 1.37 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.43 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 3.82 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 4.33 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 4.36 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 7.4 (3H, m, ArH), 7.9 (2H, m, ArH), 8.00 (1H, s, C_5-H). ^{13}C-NMR: 14.2 (q, $OCH_2\underline{C}H_3$), 14.2 (q, $COOCH_2\underline{C}H_3$), 15.2 (q, $OCH_2\underline{C}H_3$), 62.0 (t, $O\underline{C}H_2CH_3$), 63.8 (t, $COO\underline{C}H_2CH_3$), 69.2 (t, $O\underline{C}H_2CH_3$), 127.4 (s, Ph), 128.3 (d, Ph), 138.0 (2C, d, Ph), 129.6 (2C, d, Ph), 132.4 (s, C-4), 140.1 (d, C-5), 145.0 (s, C-6), 145.6 (s, C-7), 153.5 (s, C-2), 165.6 (s, $\underline{C}OOCH_2CH_3$), 171.8 (s, C-3). MS m/z: M^+ Calcd for $C_{19}H_{21}NO_5$ 343.1418. Found: 343.1361.

iii) 2-Ethoxy-4-ethoxycarbonyl-7-phenyl-3*H*-azepin-3-one **24e**: Yellow gum. IR: 1725, 1660, 1620. UV: 240 (10400), 258sh (9000), 370 (12500). ^{1}H-NMR: 1.38 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.50 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 4.40 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 4.57 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 6.90 (1H, d, J=10 Hz, C_6-H), 7.2—7.6 (3H, m, ArH), 7.7—8.0 (2H, m, ArH), 8.03 (1H, d, J=10 Hz, C_5-H).

iv) 6-Acetoxy-2-ethoxy-4-ethoxycarbonyl-7-phenyl-3*H*-azepin-3-one **24f**: Yellow gum. IR: 1765, 1725, 1660, 1620. UV: 225 (11500), 258sh (9500), 345 (7300), 385sh (6100). ^{1}H-NMR: 1.35 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.45 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 2.03 (3H, s, OAc), 4.38 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 4.50 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 7.3—7.8 (5H, m, ArH), 7.88 (1H, s, C_5-H). MS m/z: M^+ Calcd for $C_{19}H_{19}NO_6$ 357.1211. Found: 357.1175.

Methylation of Azatropolones 7 with Diazomethane i) A solution of **7a** or **7d** (each 50 mg) in CH_2Cl_2 (10 ml) was treated with a large excess of diazomethane (ethereal solution) at 0 °C for several min. After evaporation of the solvent, the residue was chromatographed and eluted with benzene to give **18a** (40 mg, 77%) or **18d** (37 mg, 70%) which were identical with the azatropolone methyl ether derived by the DDQ oxidation of **16a** or **16d**, respectively.

ii) A solution of **7e** (30 mg) in CH_2Cl_2 (5 ml) was treated with diazomethane as described above, and evaporated to give the product, the ^{1}H-NMR spectrum of which was identical with that of **18e** obtained by the DDQ oxidation of **21e**.

iii) A solution of **7c** (65 mg) in CH_2Cl_2 (10 ml) was treated with diazomethane as described above. Chromatography of the product and elution with benzene gave 7-(*p*-bromophenyl)-4-ethoxycarbonyl-3-methoxy-6-phenyl-2*H*-azepine-2-one **18c** (47 mg, 70%) as pale yellow prisms from CH_2Cl_2–Et_2O–hexane, mp 133—136 °C. IR: 1735, 1700, 1610, 1590. UV: 263 (18600), 280 (18600), 360sh (6200). ^{1}H-NMR: 1.38 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.10 (3H, s, OCH_3), 4.38 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.23 (5H, br s, ArH), 7.33 (4H, d, J=10.5 Hz, ArH), 7.80 (1H, s, C_5-H). MS m/z: M^+ Calcd for $C_{22}H_{18}BrNO_4$ 439.0418 and 441.0398. Found: 439.0377 and 441.0352.

Methylation of Azatropolones 8 with Diazomethane i) A solution of **8a** (40 mg) in CH_2Cl_2 (5 ml) was treated with excess diazomethane at 0 °C for several minutes. After evaporation of the solvent, the residue was chromatographed and eluted with benzene to give a mixture of **19a** and **20a**, which was separated by a preparative TLC (developed with CH_2Cl_2). 6-Ethoxycarbonyl-3-methoxy-4,7-diphenyl-2*H*-azepin-2-one **19a** (15 mg, 36%): yellow needles from Et_2O–hexane, mp 102—105 °C. IR: 1720, 1680, 1665, 1620, 1595. UV: 255 (20000), 300sh (10500), 350sh (7350). ^{1}H-NMR: 0.90 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.03 (3H, s, OCH_3), 4.05 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.4 (8H, m, ArH), 7.7 (2H, m, ArH), 8.30 (1H, s, C_5-H). MS m/z: M^+ Calcd for $C_{22}H_{19}NO_4$ 361.1314. Found: 361.1332. 6-Ethoxycarbonyl-2-methoxy-4,7-diphenyl-3*H*-azepin-3-one **20a** (10 mg, 23%): yellow needles from Et_2O–hexane, mp 133—135 °C. IR: 1720, 1700, 1650, 1620. UV: 232 (16700), 280 (10100), 355 (13200). ^{1}H-NMR: 0.90 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.00 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 4.05 (3H, s, OCH_3), 7.5 (10H, m, ArH), 7.80 (1H, s, C_5-H). MS m/z: M^+ Calcd for $C_{22}H_{19}NO_4$ 361.1315. Found: 361.1666.

ii) A solution of **8d** (50 mg) in CH_2Cl_2 (5 ml) was treated with diazomethane as described above. The preparative TLC (developed with CH_2Cl_2) gave **19d** and **20d**. 4-Ethoxy-6-ethoxycarbonyl-3-methoxy-7-phenyl-2*H*-azepin-2-one **19d** (12 mg, 22%): pale yellow needles from Et_2O–hexane, mp 60—63 °C. IR: 1735, 1685, 1630, 1605. UV: 254 (14000), 290 (8900), 357sh (6500). ^{1}H-NMR: 0.96 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.45 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 4.08 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 4.12 (3H, s, OCH_3), 4.22 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 7.6 (5H, m, ArH), 8.15 (1H, s, C_5-H). MS m/z: M^+ Calcd for $C_{18}H_{19}NO_5$ 329.1262. Found: 329.1226. 4-Ethoxy-6-ethoxycarbonyl-2-methxy-7-phenyl-3*H*-azepin-3-one **20d** (13 mg, 23%): yellow gum. IR: 1700, 1630. UV: 234 (17000), 350 (12500). ^{1}H-NMR: 0.87 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.53 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 4.00 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 4.07 (3H, s, OCH_3), 4.25 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 7.28 (1H, s, C_5-H), 7.4 (5H, m, ArH). MS m/z: M^+ Calcd for $C_{18}H_{19}NO_5$ 329.1261. Found: 329.1240.

Methylation of 26 with Diazomethane A solution of **26** (60 mg) in CH_2Cl_2 (5 ml) was treated with diazomethane as described above. The preparative TLC of the product (developed with CH_2Cl_2) gave **27** and **28**. 6-Ethoxy-3-methoxy-7-phenyl-2*H*-azepin-2-one **27** (25 mg, 40%): yellow needles from Et_2O–hexane, mp 130—133 °C. IR: 1665, 1600. UV: 265 (14200), 360 (4150). ^{1}H-NMR: 1.27 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 3.83 (3H, s, OCH_3), 3.90 (2H, quint, J=7 Hz, $OC\underline{H}_2CH_3$), 6.15 (1H, d, J=9 Hz, C_4-H), 6.48 (1H, d, J=9 Hz, C_5-H), 7.4 (3H, m, ArH), 7.9 (2H, m, ArH). ^{13}C-NMR: 14.5 (q, $OCH_2\underline{C}H_3$), 56.7 (q, $O\underline{C}H_3$), 65.2 (t, $O\underline{C}H_2CH_3$), 104.4 (d, C-5), 112.8 (d, C-4), 128.2 (2C, d, Ph), 130.2 (2C, d, Ph), 131.4 (d, Ph), 135.7 (s, Ph), 152.2 (2C, s, C-6 and C-7), 157.5 (s, C-3), 168.7 (s, C-2). MS m/z: M^+ Calcd for $C_{15}H_{15}NO_3$ 257.1053. Found: 257.1042. 6-Ethoxy-2-methoxy-7-phenyl-3*H*-azepin-3-one **28** (22 mg, 37%): yellow needles from Et_2O–hexane, mp 79—81 °C. IR: 1660, 1630, 1620, 1600. UV: 260 (8700), 352 (9700). ^{1}H-NMR: 1.20 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 3.83 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 3.97 (3H, s, OCH_3), 6.83 (1H, d, J=13 Hz, C_4-H), 7.33 (1H, d, J=13 Hz, C_5-H), 7.33 (3H, m, ArH), 7.75 (2H, m, ArH), ^{13}C-NMR: 15.2 (q, $OCH_2\underline{C}H_3$), 54.5 (q, $O\underline{C}H_3$), 68.7 (t, $O\underline{C}H_2CH_3$), 127.8 (2C, d, Ph), 128.9 (C, d, Ph), 129.6 (2d, Ph), 131.5 (d, C-4), 137.4 (d, C-5), 138.6 (s, Ph), 141.7 (2C, s, C-7), 149.6 (s, C-6), 155.6 (s, C-2), 173.6 (s, C-3). MS m/z: M^+ Calcd for $C_{15}H_{15}NO_3$ 257.1053. Found: 257.1055.

Benzilic Acid-Type Rearrangement of the Azatropolone 7a i) A solution of **7a** (50 mg) in MeOH (10 ml) was allowed to stand at room temperature for 3 d. Chromatography of the product and elution with benzene gave the methyl pyridine-2-carboxylate **29Ma** (42 mg, 80%). This was identical with the compound obtained *via* the DDQ oxidation of **16a**.

ii) A solution of **7a** (50 mg) and NaOAc (5 mg) in EtOH (10 ml) was refluxed for 6 h. After evaporation of the solvent, the residue was chromatographed. Elution with benzene gave ethyl 3-ethoxycarbonyl-5,6-diphenylpyridine-2-carboxylate **29Ea** (48 mg, 89%), colorless prisms from Et_2O–hexane, mp 128—130 °C. IR: 1740, 1720, 1585. UV (EtOH): 247 (15600), 300sh (9200). ^{1}H-NMR: 1.38 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.43 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.40 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 4.50 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.25 (10H, m, ArH), 8.23 (1H, s, C_4-H). MS m/z: M^+ Calcd for $C_{23}H_{21}NO_4$ 375.1469. Found: 375.1406.

iii) A solution of **7a** (50 mg) and NaOAc (5 mg) in acetone–H_2O (3 : 1) (10 ml) was refluxed for 2 h. After evaporation of the solvent, the residue was extracted with Et_2O, dried over Na_2SO_4, and concentrated. Chromatography of the residue and elution with CH_2Cl_2 gave 3-ethoxycarbonyl-5,6-diphenyl-pyridine-2-carboxylic acid **29Ha** (45 mg, 90%), colorless prisms from Et_2O–hexane, mp 160—163 °C. IR: 1770, 1730, 1710. UV (EtOH): 243, 300sh. ^{1}H-NMR: 1.38 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.51 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.33 (10H, m, ArH), 7.98 (1H, s, C_4-H). Methylation of this with diazomethane gave the methyl ester, which was identical with **29Ma** described above.

Benzilic Acid-Type Rearrangement of Azatropolones 7c, 7d, and 7e i) A solution of **7c** (50 mg) in MeOH (10 ml) was refluxed for 4 h. Chromatography of the product and elution with benzene gave methyl 6-(*p*-bromophenyl)-3-ethoxycarbonyl-5-phenylpyridine-2-carboxylate **29Mc** (42 mg, 80%) as colorless needles from Et_2O–hexane, mp 118—121 °C. IR: 1745, 1730, 1595. UV (EtOH): 253 (18600), 305sh (11900). ^{1}H-NMR: 1.40 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.00 (3H, s, $COOCH_3$), 4.40 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.2—7.4 (9H, m, ArH), 8.23 (1H, s, C_4-H). MS m/z: M^+ Calcd for $C_{22}H_{18}BrNO_4$ 439.0420 and 441.0399. Found: 439.0435 and 441.0391.

ii) A solution of **7d** (50 mg) and NaOAc (5 mg) in MeOH (10 ml) was heated for 4 h. After evaporation of the solvent, the residue was extracted with CH_2Cl_2, washed with water, dried over Na_2SO_4, and concentrated. Chromatography of the residue and elution with benzene gave methyl 5-ethoxy-3-ethoxycarbonyl-6-phenylpyridine-2-carboxylate **29Md** (42 mg, 80%), colorless prisms from Et_2O–hexane, mp 96—97 °C. IR: 1755, 1725, 1590. UV (EtOH): 238 (14400), 265sh (10000), 312 (12600). ^{1}H-NMR: 1.38 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.43 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 3.92 (3H, s, $COOCH_3$), 4.15 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 4.40 (2H, q, J=7 Hz, $COOC\underline{H}_2CH_3$), 7.4 (3H, m, ArH), 7.62 (1H, s, C_4-H), 8.0 (2H, m, ArH). MS m/z: M^+ Calcd for $C_{18}H_{19}NO_5$ 329.1262. Found: 329.1252.

iii) A solution of **7e** (30 mg) and NaOAc (5 mg) in MeOH (10 ml) was heated for 4 h. After evaporation of the solvent, the residue was extracted with CH_2Cl_2, washed with water, dried over Na_2SO_4, and concentrated. Chromatograhy of the product and elution with benzene gave methyl 3-

ethoxycarbonyl-6-phenylpyridine-2-carboxylate **29Me** (24 mg, 75%), colorless prisms from Et_2O–hexane, mp 135—140 °C. IR: 1745, 1720, 1590. UV (EtOH); 268 (13700), 290 (17100). ^{1}H-NMR: 1.37 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.00 (3H, s, $COOCH_3$), 4.38 (2H, q, J=7 Hz, $COO\underline{CH}_2CH_3$), 7.4 (3H, m, ArH), 7.73 (1H, d, J=8 Hz, C_4-H), 7.9 (2H, m, ArH), 8.18 (1H, d, J=8 Hz, C_5-H). MS *m/z*: M^+ Calcd for $C_{16}H_{15}NO_4$ 285.0999. Found: 285.0958.

Benzilic Acid-Type Rearrangement of Azatropolones 8 i) A solution of **8a** (50 mg) in MeOH (10 ml) was allowed to stand at room temperature for 3 d. Chromatography of the products and elution with benzene gave methyl 5-ethoxycarbonyl-3,6-diphenylpyridine-2-carboxylate **30Ma** (40 mg, 77%) as colorless prisms from Et_2O–hexane, mp 113—114 °C. IR: 1745, 1730, 1595. UV (EtOH): 270 (19700). ^{1}H-NMR: 1.07 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.77 (3H, s, OCH_3), 4.18 (2H, q, J=7 Hz, $COO\underline{CH}_2CH_3$), 7.43 (10H, m, ArH), 8.15 (1H, s, C_4-H). *Anal.* Calcd for $C_{22}H_{19}NO_4$: C, 73.11; H, 5.30; N, 3.88. MS *m/z*: 361.1312. Found: C, 73.32; H, 5.22; N, 3.91. MS *m/z*: 361.1289.

ii) A solution of **8a** (30 mg) in acetone–H_2O (3 : 1) (8 ml) was refluxed for 3 h. After evaporation of the solvent, the residue was extracted with Et_2O, dried over Na_2SO_4, and concentrated. Chromatography of the residue and elution with CH_2Cl_2 gave 5-ethoxycarbonyl-3,6-diphenylpyridine-2-carboxylic acid **30Ha** (19 mg, 64%) as a colorless gum. IR: 1775, 1730. UV (EtOH): 270. ^{1}H-NMR: 1.07 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.25 (2H, q, J=7 Hz, $COO\underline{CH}_2CH_3$), 7.4 (10H, m, ArH), 8.15 (1H, s, C_4-H). Methylation of this with diazomethane gave the methyl pyridine-2-carboxylate **30Ma** which was identical with the compound described above.

iii) A solution of **2c** (300 mg) in DME (100 ml) was irradiated for 8 h as described above. The reaction mixture was evaporated and the residue was treated with MeOH (10 ml) at room temperature for 3 d. Chromatography of the product and elution with benzene gave methyl 6-(*p*-bromophenyl)-5-ethoxycarbonyl-3-phenylpyridine-2-carboxylate **30Mc** (30 mg, 9.5%) as colorless prisms from Et_2O–hexane, mp 127—129 °C. IR: 1750, 1730, 1595. UV (EtOH): 273 (20300). ^{1}H-NMR: 1.12 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 3.75 (3H, s, $COOCH_3$), 4.22 (2H, q, J=7 Hz, $COO\underline{CH}_2CH_3$), 7.4 (5H, s, ArH), 7.52 (4H, br s, ArH), 8.13 (1H, s, C_4-H). MS *m/z*: M^+ Calcd for $C_{22}H_{18}BrNO_4$ 439.0419 and 441.0398. Found: 439.0409 and 441.0373.

iv) A solution of **8d** (50 mg) in MeOH (10 ml) was allowed to stand at room temperature for 3 d. Chromatography of the products and elution with benzene gave methyl 3-ethoxy-5-ethoxycarbonyl-6-phenylpyridine-2-carboxylate **30Md** (31 mg, 60%) as colorless prisms from Et_2O–hexane, mp 82—84 °C. IR: 1730, 1720sh, 1590. UV (EtOH): 258 (13900), 303 (5100). ^{1}H-NMR: 1.00 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.47 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 4.00 (3H, s, OCH_3), 4.15 (2H, q, J=7 Hz, $COO\underline{CH}_2CH_3$), 4.20 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 7.15 (5H, m, ArH), 7.67 (1H, s, C_4-H). MS *m/z*: M^+ Calcd for $C_{18}H_{19}NO_5$ 329.1251. Found: 329.12365.

Decarboxylation of Pyridine-2-carboxylic Acids 29Ha and 30Ha A solution of the carboxylic acid (**29Ha**, 20 mg or **30Ha**, 10 mg) and SiO_2 (2 g) in CH_2Cl_2 (10 ml) was concentrated to dryness. The residue was heated at 120 °C for 6 h. Chromatography of this mixture and elution with CH_2Cl_2 gave **32** (14 mg, 80%) or **33** (6.4 mg, 75%).

i) 3-Ethoxycarbonyl-5,6-diphenylpyridine **32**: Colorless prisms from hexane, mp 79—82 °C. IR: 1720, 1595. UV (EtOH): 240sh (17500), 300 (9700). ^{1}H-NMR: 1.43 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.50 (2H, q, J=7 Hz, $COO\underline{CH}_2CH_3$), 7.3 (10H, m, ArH), 8.31 (1H, d, J=2 Hz, C_4-H), 9.28 (1H, d, J=2 Hz, C_2-H). MS *m/z*: M^+ Calcd for $C_{20}H_{17}NO_2$ 303.1258. Found: 303.1175.

ii) 3-Ethoxycarbonyl-2,5-diphenylpyridine **33**: Colorless prisms from hexane, mp 137—138 °C. IR: 1718. UV (EtOH): 273 (22500), 373 (1100). ^{1}H-NMR: 1.07 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.20 (2H, q, J=7 Hz, $COO\underline{CH}_2CH_3$), 7.5 (10H, m, ArH), 8.25 (1H, d, J=2.5 Hz, C_4-H), 8.97 (1H, d, J=2.5 Hz, C_2-H). MS *m/z*: M^+ Calcd for $C_{20}H_{17}NO_2$ 303.1258. Found: 303.1217.

Benzilic Acid-Type Rearrangement of 2-Ethoxy-3*H*-azepin-3-one 24 into Ethyl Pyridine-2-carboxylates 29E (General Procedure) A solution of **24** (30 mg) in benzene was absorbed on an SiO_2 column and allowed to stand overnight at room temperature. Elution with benzene gave **29E**. **29Ea** (24 mg, 80%) was identical with the compound obtained *via* the reaction of **7a** with EtOH described above.

i) 3-Ethoxy-5,6-diethoxycarbonyl-2-phenylpyridine **29Ed**: Yield 80%. Colorless prisms from Et_2O–hexane, mp 84—85 °C. IR: 1745, 1725. UV (EtOH): 239 (14800), 264 (10100), 315 (12500). ^{1}H-NMR: 1.40 (6H, t, J=7 Hz, 2 × $COOCH_2C\underline{H}_3$), 1.43 (3H, t, J=7 Hz, $OCH_2C\underline{H}_3$), 4.15 (2H, q, J=7 Hz, $OC\underline{H}_2CH_3$), 4.35 (2H, q, J=7 Hz, $COO\underline{CH}_2CH_3$), 4.38 (2H, q, J=7 Hz, $COO\underline{CH}_2CH_3$), 7.17—7.55 (3H, m, ArH), 7.57 (1H, s, C_4-H), 7.87—8.10 (2H, m, ArH). MS *m/z*: M^+ Calcd for $C_{19}H_{21}NO_5$ 343.1419. Found: 343.1419.

ii) 2,3-Diethoxycarbonyl-6-phenylpyridine **29Ee**: Yield 75%. Colorless gum. IR: 1740, 1730. UV (EtOH): 268sh (15000), 290 (18900). ^{1}H-NMR: 1.37 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.43 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 4.38 (2H, q, J=7 Hz, $COO\underline{CH}_2CH_3$), 4.50 (2H, q, J=7 Hz, $COO\underline{CH}_2CH_3$), 7.4 (3H, m, ArH), 7.87 (1H, d, J=9 Hz, C_5-H), 8.0 (2H, m, ArH), 8.23 (1H, d, J=9 Hz, C_4-H). MS *m/z*: M^+ Calcd for $C_{17}H_{17}NO_4$ 299.1156. Found: 299.1146.

iii) 3-Acetoxy-5,6-diethoxycarbonyl-2-phenylpyridine **29Ef**: Yield 67%. Colorless gum. IR: 1765, 1725, 1600. UV (EtOH): 262 (9500), 293 (10600). ^{1}H-NMR: 1.37 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 1.40 (3H, t, J=7 Hz, $COOCH_2C\underline{H}_3$), 2.20 (3H, s, OAc), 4.33 (2H, q, J=7 Hz, $COO\underline{CH}_2CH_3$), 4.43 (2H, q, J=7 Hz, $COO\underline{CH}_2CH_3$), 7.4 (3H, m, ArH), 7.7 (2H, m, ArH), 7.87 (1H, s, C_4-H). MS *m/z*: M^+ Calcd for $C_{19}H_{19}NO_6$ 357.1211. Found: 357.1150.

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