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Synthesis of Benzo[f]quinolines and Ergolines from 5-Phenyl-6-methyl-2-pyridones

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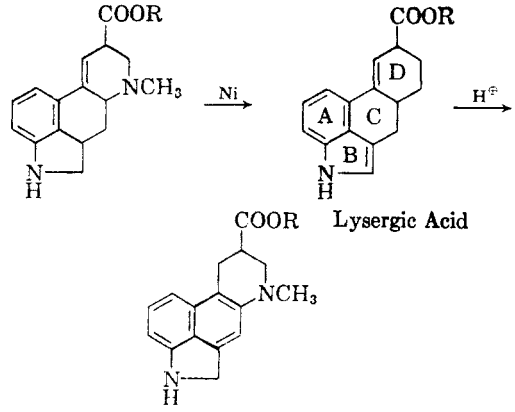
Condensation of 1-hydroxymethylene-1-phenyl-2-propanone with cyanoacetic acid derivatives, and subsequent hydrolysis, gives 5-phenyl-6-methyl-2-pyridone-6-carboxylic acid, which is converted by a new process, reaction with oxalyl chloride, to exceptionally stable pyruvic acid derivatives. Cyclization with sulfuric acid, followed by transformation, first with phosphorus pentachloride and then alcohols, affords esters of 3-chlorobenzo[f]quinoline-2,6-dicarboxylic acid. These esters, and related deschloro compounds obtained by reaction with sodium borohydride to yield novel deschloro-1,4-dihydro compounds followed by rearomatization to benzo[f]quinolines, are nitrated at position 7. The nitro esters are reductively cyclized in the presence of palladium and acetic acid to corresponding lactams (aromatic ergoline derivatives), known to be intermediates in synthesis of dihydrolysergic acid. A number of related experiments, especially those involving preparation and reactions of 5-phenyl-6-methyl-2-pyridone-3- and 4-carboxylic acids, are described, and some data are presented to indicate the tautomeric states of these pyridones.

Lysergic acid, the structural component common to the ergot alkaloids, already has a rather long history of chemical investigation. The nature of the tetracyclic ring system was determined through the efforts of W. A. Jacobs[1] and his collaborators, and the position of the extra double bond later ascertained through the work of A. Stoll[2] and his school. There followed much synthetic work, in which ring D was closed upon various naphthalenes and naphthostyrils[3] and their reduced counterparts. These syntheses first confirmed the structural investigations by means of a synthesis of dihydrolysergic acid[4] and related compounds[5-7] and finally culminated in total synthesis of lysergic acid itself.[8] Two outstanding features of lysergic acid have been responsible for making the chemistry associated with this molecule both difficult and unusual. The first of these is the peculiar mode of fusion of the four rings (ergoline ring system) which is quite different from that found in the equally complex (or more so) but more common indole alkaloids of β-carboline and strychnos varieties, although all of these alkaloids may be based biogenetically upon tryptophane.[9] The second is the unusual placement of double bonds in such a situation, exocyclic to ring C, as to result in lability[2,6] and a pronounced tendency for irreversible shift of these double bonds into ring C with consequent formation of a naphthalene.[5,7,8] This lability is also reflected in tricyclic analogs,[6,8,10,11] lacking ring D—*i.e.* in benz[*cd*]indolic ketones which revert readily to naphthols—and in fact the success of the entire scheme finally employed in total synthesis of lysergic acid[8] depended upon introduction at the last step of the ring B double bond without disturbing the one which had already been placed correctly in ring D:



Thus it was evident to us at the outset that a second total synthesis of lysergic acid *per se*, based upon any attempt at reduction or isomerization of an already existing aromatic A/C system, was not likely to succeed. However, the possibility of elaborating the ergoline ring system in a way different from the classical approach compelled our attention, particularly in view of the fact that one such alternative scheme had already been pro-

(1) W. A. Jacobs and L. C. Craig *et al.*, *J. Biol. Chem.*, **115**, 227 (1936); **125**, 289 (1938); *J. Am. Chem. Soc.*, **60**, 1701 (1938).

(2) A. Stoll, A. Hofmann, and F. Troxler, *Helv. Chim. Acta*, **32**, 506 (1949).

(3) W. A. Jacobs and R. G. Gould, *J. Biol. Chem.*, **126**, 67 (1938); **130**, 399, 407 (1939).

(4) F. C. Uhle and W. A. Jacobs, *J. Org. Chem.*, **10**, 76 (1945).

(5) A. Stoll, T. Petrzilka, J. Rutschmann, and W. Schlientz, *Helv. Chim. Acta*, **33**, 67, 375, 2254, 2257 (1950).

(6) A. Stoll and T. Petrzilka, *Helv. Chim. Acta*, **36**, 1125 (1953).

(7) F. R. Atherton, F. Bergel, A. Cohen, B. Heath-Brown, and A. H. Rees, *Chem. & Ind. (London)*, 1151 (1953).

(8) E. C. Kornfeld, E. J. Fornefeld, G. B. Kline, M. J. Mann, D. E. Morrison, R. G. Jones, and R. B. Woodward, *J. Am. Chem. Soc.*, **78**, 3087 (1956).

(9) See A. Feldstein, *Experientia*, **12**, 475 (1956) for possible biogeneses of lysergic acid.

(10) F. C. Uhle, *J. Am. Chem. Soc.*, **71**, 761 (1949); **77**, 3544 (1955); **79**, 102 (1957).

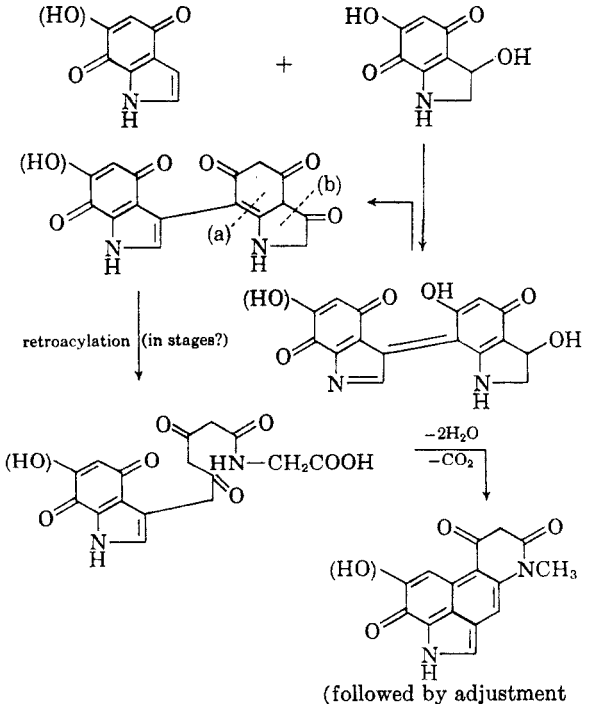
(11) C. A. Grob and H. U. Schmid, *Helv. Chim. Acta*, **33**, 1796, 1955 (1950).

pounded,[12] hinging upon Pschorr ring closure between rings A and D. A remaining possible approach consisted of closure of rings B and C after first establishing a 5-phenylnicotinic acid (A–D) molecule, and is the thesis of the work described here. We were motivated as well by the possibility that intermediates, or derivatives thereof, involved in the building of the ergoline framework by a new route, might have interesting pharmacodynamic properties,[13] and also by (admittedly speculative) considerations of possible *in vivo* metabolites of lysergic acid derivatives.[14]

(12) H. Plieninger, M. Schach von Wittenau, and B. Kiefer, *Ber.*, **91**, 1898, 1905, 2095 (1958).

(13) A number of relatively simple compounds, *i.e.* 2-aminotetralin derivatives, 3-indolylmethylpiperidines, 3-phenylpiperidines, and open-chain analogs, only remotely related to lysergic acid, have been found to possess oxytocic, sympatholytic, hypotensive and antiserotonin activity. For leading references and work in this area, see J. Cymerman-Craig, B. Moore, and E. Ritchie, *Austr. J. Chem.*, **12**, 447, 453 (1959); K.-O. Haustein, *Naturwiss.*, **14**, 450 (1959); H. Plieninger, *Ber.*, **86**, 25 (1953); A. M. Akkermann *et al.*, *Rec. trav. chim.*, **70**, 899 (1951); **73**, 629 (1954); H. Bader and W. Oroshnik, *J. Am. Chem. Soc.*, **79**, 5686 (1957).

(14) See K. Freter, J. Axelrod, and B. Witkop, *J. Am. Chem. Soc.*, **79**, 3191 (1957); and M. Slaytor, J. N. Pennyfather, and S. E. Wright, *Experientia*, **15**, 111 (1959). Evidence so far indicates that lysergic acid derivatives are converted to oxy-derivatives *in vivo*. At one time (early in 1959) we were giving consideration to an hypothesis concerning alternative origin of lysergic-like compounds *in vivo* from endogenous catecholamines and/or administered mescaline, which, summarily, proceeded along the following tentative lines:



(followed by adjustment of oxidation state)

See J. D. Bu'Lock and J. Harley-Mason, *J. Chem. Soc.*, 2248 (1951), and S. Senoh, B. Witkop *et al.*, *J. Am. Chem. Soc.*, **81**, 6231, 6236 (1959) for formation and disproportionation of aminochromes and further references to material centering about the "indole hypothesis."

As indicated very briefly in a preliminary communication,[15] we began our work by exploring condensation of compound *1*, the formyl (hydroxymethylene) derivative of phenyl-2-propanone,[16] with amino compounds. This particular 1,3-dicarbonyl compound, by virtue of the fact that it consists in part of a phenylacetaldehyde structural moiety, is rather unstable and possibly for this reason has not been prepared or used in reactions as frequently as some other, more stable, formyl ketones. For example, there seems to be no record of its reaction with hydrazine to yield pyrazole *2* (R = H) and we found that it indeed decomposed to a great extent in the presence of concentrated, strong bases such as hydrazine and ammonia. In dilute hydrazine solution, however, successful conversion to *2* (R = H), known from two alternative sources[17,18] was achieved readily, and similar preparation of the phenylhydrazine-derived pyrazole *2* (R = C_6H_5) could also be carried out, thus additionally characterizing *1* and indicating the way in which it might be used in other reactions. Attention was then directed to the reaction of *1* with cyanoacetic acid derivatives as a means of obtaining desired pyridones related to 5-phenylnicotinic acid. Depending upon the manner in which condensation of *1* with cyanoacetamide was carried out, two different cyanopyridones could be obtained. When piperidine was used to promote the reaction under mild conditions (in methanol), following, with slight modifications (see Experimental) a well-known procedure,[19–21] a low yield of cyanopyridone *4* was obtained. This compound was hydrolyzed readily to the acid *8* with hydrochloric acid, as expected. On the other hand, when the sodium salt of *1* was condensed directly with cyanoacetamide in methanol according to a recently published modified procedure,[22] a different cyanopyridone *3* was obtained. This compound, obtained in better yield than *4*, could not be hydrolyzed with hydrochloric acid under the same conditions as used in hydrolysis of *4*, and so was assigned structure *3* in which an *ortho* (4-) methyl group blocks the cyano

(15) G. N. Walker and B. N. Weaver, *J. Org. Chem.*, **25**, 484 (1960).

(16) G. N. Walker, *J. Org. Chem.*, **23**, 34 (1958); in this article the correct structure of this compound was made apparent, although it had been prepared earlier and assigned the wrong structure by Roch, *Compt. rend.*, **220**, 322 (1945).

(17) W. E. Parham and J. L. Bleasdale, *J. Am. Chem. Soc.*, **72**, 3843 (1950).

(18) J. A. Moore and R. W. Medeiros, *J. Am. Chem. Soc.*, **81**, 6026 (1959).

(19) J. C. Bardhan, *J. Chem. Soc.*, 2223 (1929).

(20) A. H. Tracy and R. C. Elderfield, *J. Org. Chem.*, **6**, 63 (1941).

(21) W. Wenner and J. T. Plati, *J. Org. Chem.*, **11**, 751 (1946).

(22) R. K. Blackwood, G. B. Hess, C. E. Larrabee, and F. J. Pilgrim, *J. Am. Chem. Soc.*, **80**, 6244 (1958). This paper has leading references to other related pyridone syntheses.

group sterically. By way of confirming the assigned structures *3* and *4*, it was also observed that the same steric effect is present in simpler pyridones; with hydrochloric acid, 3-cyano-6-methyl-2-pyridone[19] and 3-cyano-5,6-dimethyl-2-pyridone[20] are hydrolyzed readily to corresponding acids, but 3-cyano-4,6-dimethyl-2-pyridone[19] is not. The low (9%) yield of *4* led us to try alternative preparations of intermediates hydrolyzable to acid *8*. By deliberately subjecting the same methanol reaction solution, which had produced *4*, to a period of heating *in situ* after acidification with acetic acid, the nitrile group was converted to the methyl imino ether, and compound *5* could be isolated, usually in somewhat better (20–30%), although rather capricious, yield. Later another improvement was found in using ethyl cyanoacetate in place of cyanoacetamide, which afforded compound *6* in 20% yield or better when the reaction was run in methanol. The formation of pyridones by reaction of 1,3-dicarbonyl compounds with ethyl cyanoacetate is known[19,23]; however, in this case ammonia is not required, and the reaction is accompanied by ester exchange with the solvent. As in early work,[23] no pyridone was formed until after the base-catalyzed, initial reaction mixtures had been acidified, although in the present cases very mild conditions always were sufficient, a fact which again reflects the great reactivity of compound *1* and its derivatives.[16] Structure *6* was established by three facts: first, that *6* was hydrolyzed to acid *8;* second that *6* reacted readily with primary amines, giving corresponding amides *7* and demonstrating the presence of a highly reactive ester group (see Experimental for several examples); and third that both *6* and *7* were inert to palladium-catalyzed hydrogenation, which excludes any enol-lactone formulation such as *6a*.

Confirmation of structure *8* was adduced by conversion *via* standard methods to the corresponding 2-chloro acid chloride, thence to the 2-chloroethyl ester, and subsequently, by catalytic hydrogenation (dechlorination) to the 5-phenyl-6-methylnicotinate *9*. At this point we carried out a reaction of *9* with ethyl oxalate and sodium methoxide, and isolated a small amount of expected enol, as well as a corresponding enol methyl ether *10*, although the reaction was a very poor one. There was no success in attempts to cyclize these compounds. Their preparation, however, provided further evidence that the preceding structures *4–9* were correct, for if a compound such as *10* were to be prepared from a pyridine-ester corresponding to *3*, one could anticipate enol-lactone formation, and this was not in evidence.

Before proceeding with further efforts to convert the 5-phenyl-6-methylpyridines into tricyclic compounds, we turned to examination of a preparative scheme similar to the foregoing one, based upon compound *11*, which afforded a certain amount of additional interesting information. The enolic substance *11*, although apparently even less stable than *1*, could be prepared by Claisen reaction of phenylacetone with ethyl oxalate, using approximately the same conditions as with ethyl formate, and this enol, like *1*, yielded a pyridone *12* when condensed with cyanoacetamide in methanol in the presence of piperidine. Here again, two products are theoretically possible, but the alternative one *12a* could not be obtained when an attempt was made to utilize the sodium salt[22] of *11* in a similar condensation. As a possible structure for the lone product obtained in this case, *12a* is not consonant with previous work on similar keto-ester condensations[19,24] and is excluded by the following facts. The diacid *14*, obtained from the cyanopyridone ester by acid hydrolysis, readily formed a cyclic anhydride *15*, unmistakable as such from the infrared spectrum (5.38 and 5.57 μ) and its uncatalyzed reaction with alcohols to yield acid esters. The extreme ease with which the adjacent 3- and 4-groups in *12* and *14* interact, is due presumably to the steric compaction set up by the adjacent phenyl group, and is reflected in the unusually low wave length of anhydride absorption. It is evident as well in the fact that *12*, with acetic anhydride, also cyclized, giving a product to which we have assigned structure *13*, consistent with analysis and the presence of peaks at 5.64 and 5.82 μ in the infrared spectrum. We entertained a hope that diacid *14*, which could be obtained in better yield than *8*, might serve as a useful intermediate in further work, but this idea had to be abandoned when it was found that decarboxylation of *14*, through prolonged boiling with hydrochloric acid, formed compound *16*, rather than *8;* comparison (melting point; spectra) of *16* and its methyl ester with *8* and *6*, respectively, showed them to be quite different compounds. The fact that the 3-carboxyl group of *14* is lost in preference to the one at position 4 may be ascribed to a combination of steric and electronic factors, since decarboxylation of *8* does not occur under the same conditions. Not only is the 3-carboxyl group labilized to some extent by both the phenyl group (vinylogous similarity to phenylacetic acid) and the adjacent pyridone carbonyl, but also the 4-carboxyl group probably exerts an extruding influence. We believe, furthermore, that another factor governs the difference in chemical behavior between the first series of compounds *4–8* and the second series *11–16*, and this is shown in the way the formulas are written: The compounds of the first series apparently have a greater tendency to exist in the 2-hydroxypyridine form than do the

(23) H. Rogerson and J. F. Thorpe, *J. Chem. Soc.*, **87**, 1685 (1905).

(24) J. R. Stevens and R. H. Beutel, *J. Am. Chem. Soc.*, **65**, 449 (1943).

CHART

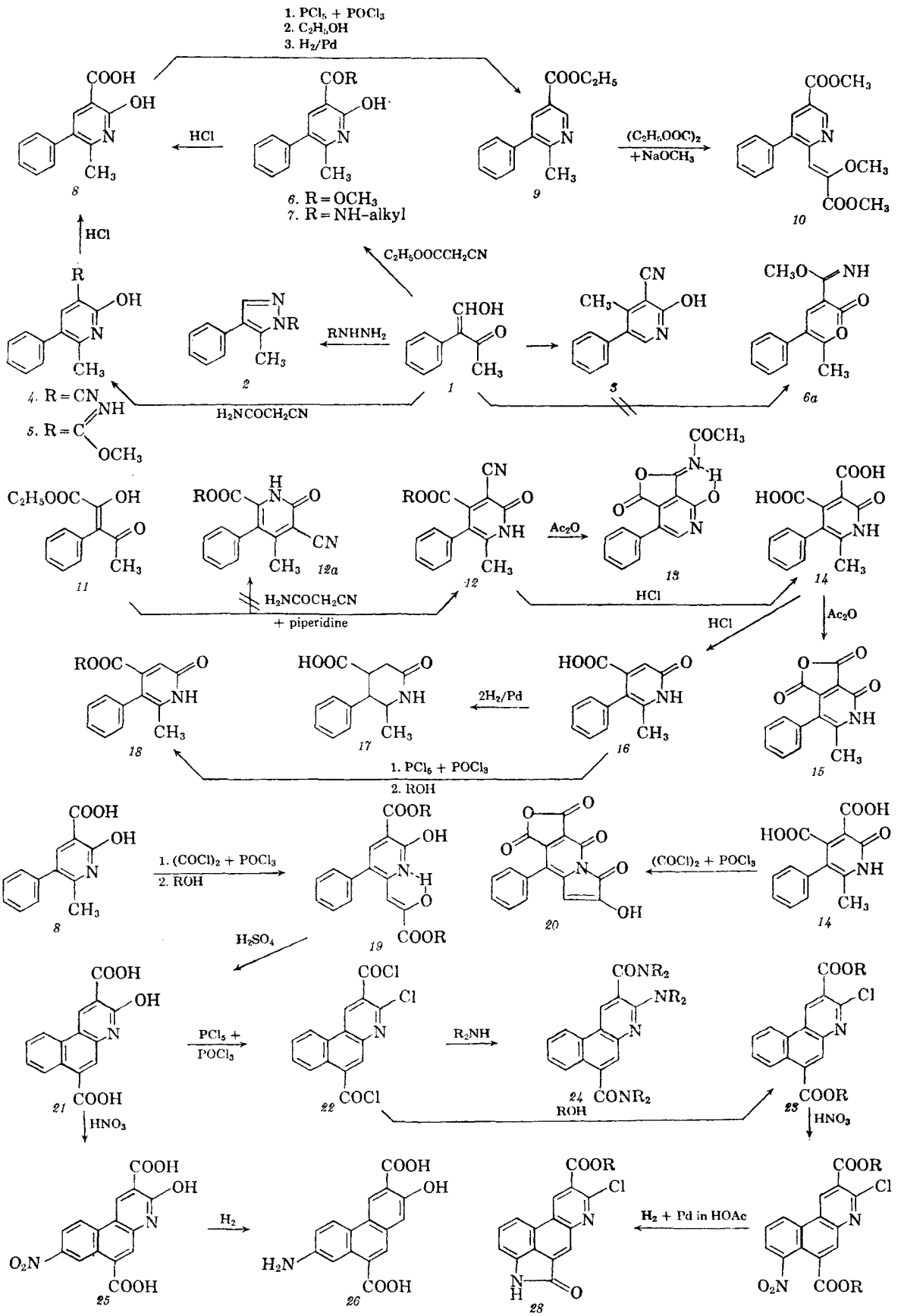
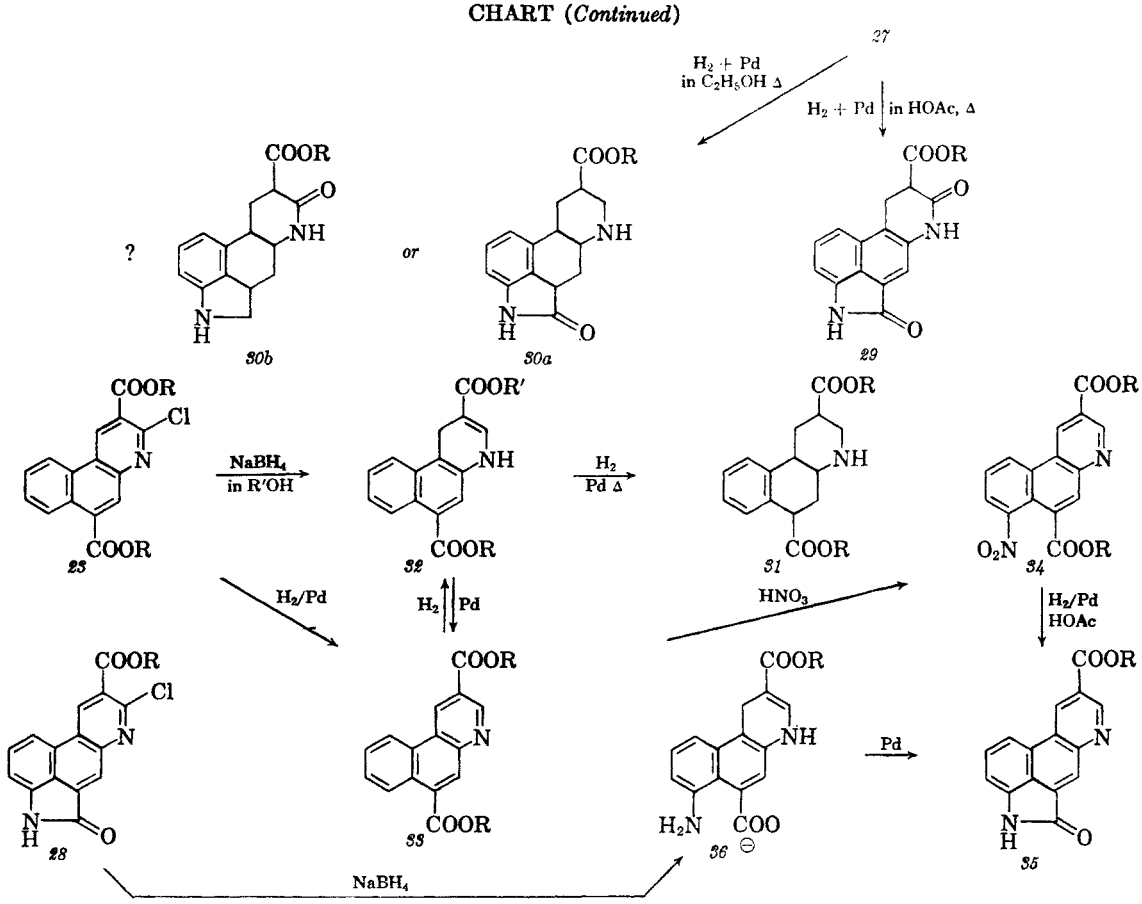

1. PCl5 + POCl3
2. C2H5OH
3. H2/Pd
HCl
6. R = OCH3
7. R = NH-alkyl
(C2H5OOC)2
+NaOCH3
HCl
C2H5OOCCH2CN
RNHNH2
H2NCOCH2CN
4. R = CN
5. R = C(NH)OCH3
Ac2O
HCl
H2NCOCH2CN
+ piperidine
2H2/Pd
1. PCl5 + POCl3
2. ROH
1. (COCl)2 + POCl3
2. ROH
(COCl)2 + POCl3
H2SO4
PCl5 +
POCl3
R2NH
ROH
HNO3
H2
H2 + Pd in HOAc

CHART (*Continued*)



compounds of the second series which seem to prefer the tautomeric 2-pyridone form, at least insofar as chemical reactions are concerned.[25] Several pieces of evidence in addition to that supplied by decarboxylation of *14* were found to support this idea, as follows: (a) Compounds *4–8* showed consistently higher melting points than similar compounds in the second series. (b) Whereas compounds *6*, *7*, and *8* were wholly resistant to palladium-catalyzed hydrogenation in the presence of acetic acid at 80°, the acid *16* was reduced rather readily under these conditions, giving the somewhat unstable piperidone *17*, which was also characterized as the corresponding methyl ester. This indicates a greater degree of resonance-stabilization—*i.e.* existence in the more "aromatic" form—in *8* than in *16*. (c) Whereas acid *8* formed a 2-chloro derivative when treated with phosphorus pentachloride–phosphorus oxychloride, and the 2-chloro group survived subsequent treatment with alcohol, the acid *16*, when subjected to the same process, formed no 2-chloro derivative but rather the pyridone ester *18*. An effect of the same type was also observed in esterification, inasmuch as compound *16* could be converted smoothly to a corresponding ester under Fischer esterification conditions while compounds *4* and *8* resisted this treatment. (d) Still another point of evidence in favor of the pyridone formulation for *14* and its derivatives was found in formation of compound *20*, as described later in another connection.

If one makes the reasonable assumption that the (potential) aldehyde group of *1* and the α-keto ester group of *11* are, respectively, the more reactive moieties in those compounds, then the rule, first laid down by Bardhan[19] and later supported by further eidence,[20,24,26] is also upheld in the cases described here. This rule, in harmony with modern electronic reasoning, states that the more reactive (and/or least hindered) group of a 1,3-dicarbonyl compound tends to condense with the methylene group, rather than the amino group, of cyanoacetamide. The exceptional preparation of compound *3* may be comprehended by assuming that the hydroxymethylene group of *1* has an unusually strong tendency to form an anion, comparable in stability to a carboxylate ion, and that when the sodium salt of *1* is employed in reaction with cyanoacetamide, the methyl ketone moiety, being the only reactive carbonyl group available at first, must perforce react with the methylene group of cyanoacetamide. Alternative explanations, based upon steric effects in presumed

(25) For the sake of convenience, however, all these compounds are named as 2-pyridones.

(26) See M. L. Scott, L. C. Norris, and W. F. Bruce, *J. Am. Chem. Soc.*, **67**, 157 (1945).

piperidine-eneamine intermediates derived from *1* and *11* appear to be less satisfactory.

Realizing that compound *8* was the point at which to attack the main problem, namely the building up of a tricyclic compound having the proper substituents, we resumed efforts to transform it into a pyruvic acid derivative suitable for cyclization to desired benzo[*f*]quinoline. Acceptable solutions are now available to the long-standing problem of how best to bring about reaction of α-picolines[27] and α'-methyl-α-pyridones[28] with ethyl oxalate, but we were not aware of these findings at the time when we were faced with the need to prepare such derivatives in this work, and in any event it was desirable to avoid difficult procedures or tedious routes involving protective groups. Therefore a new process was developed which utilized acidic conditions and thus was directly applicable to pyridones, consisting of the reaction of methyl pyridones such as *8* with oxalyl chloride. Phosphorus oxychloride was required as a catalyst for the reaction. Best results in converting *8* to an acid chloride complex corresponding to *19* were obtained by using somewhat more than two equivalents of phosphorus oxychloride, an excess of oxalyl chloride, and a short period of heating, gauged by cessation of hydrogen chloride evolution. The crystalline phosphorus-chlorine complex of the enolic acid chloride resulting from this reaction could not be characterized precisely *per se*, but it readily afforded an ester or the acid, *19*, depending upon whether it was treated subsequently with an alcohol or water. In comparison with ordinary glyoxylic esters or acids, these ferric-chloride positive compounds are remarkably stable. This stability, and the lack of hydroxyl absorption in the infrared spectrum of the ester, are best explained by the reasonable assumption that the enolic group is completely chelated with the nitrogen atom; a genuine zwitterionic formula in the case of the ester is not likely in view of the relatively low melting points of the compounds and the lack of typical ionic bands in the infrared.

An attempt was made to convert the diacid *14* with oxalyl chloride into a compound like *19*, but divergent results were obtained. A deep red, crystalline, chlorine-free material resulted, and analysis, spectra and other properties excluded any reasonable formula other than the anhydride lactam *20* for this substance. Thus, once again, the tendency for compound *14* and its congeners to exist in the pyridone form was pointed out.

Milder conditions having failed to give useful results, the enolic acid *19* (R = H) was cyclized with concentrated sulfuric acid, and a good yield of the benzo[*f*]quinolone *21* was obtained.[29] A portion of the sulfuric acid solution was treated with alcohol in order to obtain the corresponding diethyl ester as well for purpose of characterization, for compound *21*, in common with similar acids described earlier,[3] was a refractory substance (m.p. >360°). In its infrared spectrum there was no longer seen the 700-cm.$^{-1}$ monosubstituted benzene peak which had been present in all the compounds preceding it, and the ferric chloride test was negative. After conversion of *21*, *via* the chloro acid chloride *22*, to corresponding chloro esters *23*, a characteristic ultraviolet spectrum, very much like that of a phenanthrene, also confirmed the tricyclic structure. The reaction of crude *22* with alcohols was found to result in formation of a small amount of 3-hydroxy diester as well as *23*, indicating a not surprising lability of the 3-chloro group under acidic conditions. Similarly, the chlorine was responsive to bases, and in fact reaction of *22* with excessive amounts of secondary amines (except diethylamine) afforded aminodiamides *24*, several examples of which were prepared (see Experimental). Thus we were forewarned of the necessity for brisk handling of 3-chlorobenzo[*f*]quinolines in subsequent manipulations.

At this point there remained two major problems: removal of the group at position 3 and introduction of a nitrogen atom at position 7 of the benzo[*f*] quinoline, in order to complete the synthesis of an aromatic ergoline. The solutions of these two problems were mutually interdependent, as will be evident in the remaining discussion.

Nitration of *21* was tried first, since there is ample precedent in the early work of Jacobs and Gould[3] for nitration of such benzo[*f*]quinolines principally at position 7. With boiling nitric acid, *21* yielded two easily separated mononitro derivatives. Because of the extreme lack of solubility of these compounds in organic solvents, they were reduced in dilute ammoniacal solution, in the presence of palladium-charcoal. Under these conditions smooth uptake of three equivalents of hydrogen was observed in each case. However, in neither case did lactam formation take place upon subsequent treatment of the amino acids with mineral acid. Thus it became evident that nitration of *21* had provided for the most part the 8-nitro compound *25*, the second isomer, formed in smaller amount being probably the 10-nitro isomer. It was also immediately apparent, when these results were compared with the literature precedents,[3] that the 3-hydroxyl group must be responsible for the unfavorable orientation of NO_2^+ attack upon *21*, exerting an electrondonating influence throughout the ring system at points *ortho* and *para*, and vinylogously equivalent to these, relative to itself. One reasoned that if the hydroxyl group were to be replaced by an innocuous hydrogen atom or

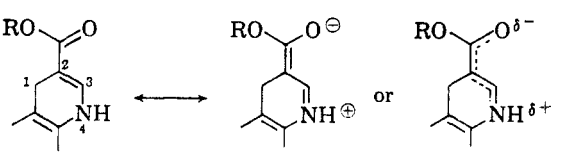
(27) E. D. Amstutz and M. M. Besso, *J. Org. Chem.*, **25**, 1688 (1960).

(28) R. Adams and W. Reifschneider, *J. Am. Chem. Soc.*, **81**, 2537 (1959).

(29) For review of alternative syntheses of benzo[*f*]-quinolines, see L. P. Walls in Elderfield, *Heterocyclic Compounds*, Vol. 4, Chapter 5; Wiley, New York, 1952.

slightly electron-withdrawing chlorine, the normal preferred attack of positive ions at the least-hindered α-naphthalene-like position 7 might then be achieved. This proved to be the case. When chloro diesters *23* were nitrated, under conditions (cold, fuming nitric acid) similar to those used earlier[3] and appropriate to the slightly unstable nature of *23*, the main product in each case was the desired 7-nitro derivative *27*. This was demonstrated by reduction of *27* under oxindole-forming conditions[30] (acetic acid) in the presence of palladium, which provided the chloro lactam *28*. It seemed that it should then be an easy matter to remove the chlorine reductively, but unexpected difficulty arose. The chloroatom in *28*, probably by virtue of its attachment to a highly electron-delocalized, stable nucleus, proved resistant to all efforts at hydrogenolytic removal under the mildly alkaline or neutral conditions which ordinarily serve for very efficient dechlorination of simple pyridines and quinolines. Under more strenuous conditions it was possible to bring about over-reduction of *27*—*i.e.* further reduction of *28*—but when this occurred the process did not result in mere dechlorination. Upon reduction of *27* (R = C_2H_5) in acetic acid at 80° (palladium), an extra mole of hydrogen was taken up past the point of nitro group reduction. The product, isolated in low yield, was a dilactam, *29* (R = C_2H_5), evidently formed through intervening solvolysis of the chlorine. When *27* (R = C_2H_5) was hydrogenated in alcohol under the same conditions (75°) the reduction went even further, continuing until a total of nearly eight moles of hydrogen had been consumed. From this reaction there was isolated, again in low yield, a rather unstable compound for which structure *30a* (R = C_2H_5) seems the most reasonable, considering the manner of its formation; however, the infrared data (2.96, 5.83, 5.94, and 6.17 μ) are in somewhat better agreement with structure *30b*, which conceivably might have arisen through involvement of the oxindole in a 1,4- or 1,6-addition of hydrogen to the extended, conjugated naphthalene system and, concurrently, solvolysis once again at the 3-position. Alternatively, it is also possible that ring A was reduced instead of ring C.

Although the foregoing experiments did not lead to useful intermediates, they provided information which was helpful when work was resumed with compounds *23*. In preliminary efforts to remove the chlorine from *23* it was again found that catalytic reduction, once initiated, had a strong tendency to proceed past the one-mole stage of chlorine-expulsion. Although compound *33* (R = C_2H_5) was isolated from one small-scale, palladium-catalyzed reduction of *23* (R = C_2H_5), the experiment was not reproducible and later repetition provided also a dihydro compound *32* (R = C_2H_5), under nearly the same conditions. When an elevated temperature was employed, complete, or nearly complete, reduction of the quinoline system took place, as in formation of *30*, giving an unstable substance, poorly characterized even as the hydrazide, which may have been either *31* or a corresponding compound incorporating one extra double bond in an unknown location. However, it was also found that chloro esters *23* react readily with sodium borohydride in alcohols, and preliminary work demonstrated that the same type of dihydro compound *32* was formed as had previously been obtained in one of the palladium hydrogenations. Further examination of this borohydride reduction in various solvents revealed that there is ester exchange at the 2-carboxyl group when the ethyl ester is reduced in methanol (or *vice versa*). The dihydro esters *32* were bright yellow compounds, and thus at first it was thought that they were 3,4-dihydro-benzo[*f*]quinolines.[31] The ultraviolet spectra of compounds *32*, although more naphthalene-like than those of the fully aromatic compounds, were too complex to provide unequivocal proof for any particular location of the double bond in this case. However, the infrared spectra of *32*, and some other properties as well, were definitive, and forced us to conclude that we had in hand 1,4-dihydro compounds. Thus, the infrared spectra consistently showed an unusual, strong peak at 6.07–6.08 μ, as well as strong NH absorption at 3.01–3.05 μ and ester peaks at 5.80–5.86 μ. The NH band excludes a genuine double bond to the nitrogen (1,2-dihydro), but the 6.07-μ peak, not seen in spectra of any of the fully aromatic compounds, can represent only $-\overset{|}{\underset{\oplus}{N}}=$ and/or conjugated double bond. This leads to the only reasonable interpretation, namely that the unsaturated amino ester grouping, in common with other β-iminocarbonyl systems, is an electron-delocalized moiety—*i.e.* group interaction confers a certain amount of amide-like character:



This formulation of compounds *32* provides a satisfactory explanation, not only for the infrared spectra, but also for (1) their formation and stability—*i.e.* persistence as such—in the presence

(30) G. N. Walker, *J. Am. Chem. Soc.*, **77**, 3844 (1955).

(31) In analogy with previously described, bright yellow 1,2-dihydro-3-acetylquinolines; see R. B. Woodward and E. C. Kornfeld, *J. Am. Chem. Soc.*, **70**, 2508 (1948). It is relevant to the present discussion to note that 1,4-dihydro-3-acetylquinoline melts 80° higher than 3-acetylquinoline, from which it is prepared by nickel-catalyzed reduction. Unfortunately, no infrared spectra were reported in this paper.

of sodium borohydride, (2) the observed ester-exchange during their preparation, (3) their lack of solubility in acids and lability in respect to same, and (4) their unusually high melting points in comparison with the closely related *23* and *33*. There also may very well be a connection between the behavior observed with these dihydro compounds and the difficulties experienced by Uhle[4] in reducing a quaternary salt of *35*, which is based essentially upon the same benzo[*f*]quinoline nucleus. Finally, there is no lack of precedent for the formation of 1,4-dihydro compounds in the reduction of quinolines.[32]

In any event, the nature of compounds *32* having been established, presumptively at the time, it was a simple matter to reconvert the methyl ester *32* to the aromatic, and now dechlorinated, compound *33*, using palladium-charcoal at a moderate temperature, and thus, finally, we had a way to obtain appreciable quantities of *33*. From this point on, the work consisted merely of nitrating *33* under the same conditions which had already been found suitable in the case of *23*, and converting the resulting *34* to *35*, using the same reductive lactam closure as was used in preparing *28*.

It was also possible, in the end, to utilize the knowledge gained concerning selective action of sodium borohydride upon the chlorine-substituted heterocyclic ring in converting chloro lactam *28* to *35*, although the yield of *35* obtained in this way was very low. It is probable that sodium borohydride opened the lactam ring of *28* to a large extent as well as attacking ring D. The product, expressed as *36*, was very insoluble in nonpolar solvents and apparently underwent only partial lactam reclosure during rearomatization. The acid-instability of the material *36* precluded any further efforts with it.

Compound *35* (R = CH_3) was identical in all respects with Uhle's material of the same formula,[4] and the acid corresponding to *35*, obtainable from *35* by hydrolysis, had already been converted by Uhle and Jacobs[4] to a mixture of diastereoisomers of dihydrolysergic acid. Thus, the present synthesis can be considered an alternative, although hardly practical, synthesis *via* relay of that compound. In comparison with the relatively short methods worked out originally,[4] and later modified by Stoll and Petrzilka,[5,6] for preparing aminonaphthostyrils and cyclizing their malonaldehydic derivatives, we calculate at present an over all yield of 1.3% in the eleven-step conversion of phenylacetone to compound *35*. However, we feel that some of the methods employed here, and possibly a few of the more interesting intermediates, will be useful in future investigations along other lines.

(32) See R. C. Elderfield, Chapter 1 in Vol. 4, of *Heterocyclic Compounds;* Wiley, New York, 1952; pp. 271–279.

EXPERIMENTAL[33]

1-Hydroxymethylene-1-phenyl-2-propanone (I). Dry sodium methoxide, freshly prepared from 69 g. (3 g.-atoms) of sodium, was powdered, suspended in 1 l. of anhydrous ether, and, while swirling and cooling in ice, was treated with a solution of 380 g. (2.84 moles) of phenyl-2-propanone and 300 g. of ethyl formate in 500 ml. of anhydrous ether. When the solid methoxide had dissolved the solution was allowed to stand, protected from moisture, overnight at room temperature. Addition of water (1.5 l.) and subsequent isolation of the enol in the usual way by acidification (dilute hydrochloric acid) of the washed aqueous solution and extraction with ether, afforded 400 g. (87%) of red oil, giving a strong ferric chloride test, which crystallized completely after storage for several weeks in a closed container at 0°. Recrystallization from ether gave a pure sample, m.p. 69–71°.

Anal. Calcd. for $C_{10}H_{10}O_2$: C, 74.05; H, 6.22. Found: C, 74.21; H, 6.37.

The crude product was quite suitable for further work.

Ethyl 2-keto-3-phenyl levulinate (II). Condensation of 81 g. (0.604 mole) of phenyl-2-propanone and 96 g. (0.658 mole) of ethyl oxalate in the presence of dry sodium methoxide, freshly prepared from 16 g. (0.695 g.-atom) of sodium, in 1 l. of dry ether, by the same procedure as was used in the preceding experiment, gave 110 g. of deep red oil. Upon standing for several days, the material deposited 15 g. of a by-product, which was removed by filtration with the aid of a little ether; analysis of a sample of this material (recrystallized from ether–ethyl acetate), m.p. 197–199°, indicated that it was *methyl-2-phenylcyclopentane-1,3,4-trione-5-glyoxalate.*[34] The compound gave a deep green ferric chloride test.

Anal. Calcd. for $C_{14}H_{10}O_6$: C, 61.32; H, 3.68. Found: C, 61.34; H, 3.68.

The clarified oil, after drying briefly *in vacuo*, weighed 80 g. (56% yield). It was stored at 0° in a closed container until used. A crystalline sample of this enol was never secured. Attempts to characterize it as a pyrazole by reaction with hydrazine resulted in decomposition. The copper salt could not be purified successfully.

3-Methyl-4-phenylpyrazole (II. R = H). A cold solution of 3 g. of 1-hydroxymethylene-1-phenylpropanone in 70 ml. of ethanol was treated with excess alcoholic hydrazine. The solution was warmed briefly on a steam cone, evaporated to a volume of *ca.* 20 ml., cooled in ice, and treated gradually with 15% hydrochloric acid until the *p*H of the mixture was 8. Enough water was added to produce a homogeneous solution, which was then chilled and scratched. The crystals were collected, washed with 3:1 aqueous methanol, and dried; the yield of product, m.p. 140–143°, was 2.1 g. Recrystallization from aqueous alcohol gave colorless flakes, m.p. 142–144° (lit. m.p. 141°[17]; 142°[18]).

Anal. Calcd. for $C_{10}H_{10}N_2$; C, 75.92; H, 6.37; N, 17.71. Found: C, 75.93; H, 6.40; N, 17.71.

λ_{max}^{Nujol} 3.14–3.20 (bonded), 6.21 and 6.29 μ, as well as a sharp peak at 699 $cm.^{-1}$

1,4-Diphenyl-3-methylpyrazole (II. R = C_6H_5). Reaction of 5 g. of 1-hydroxymethylene-1-phenylpropanone with 5 g. of phenylhydrazine in 50 ml. of ethanol under reflux for 1 hr. afforded 3.4 g. of crystals, m.p. 155–160°. Recrystallization from aqueous ethanol gave colorless flakes, m.p. 158–160°; λ_{max}^{Nujol} 6.25 μ.

Anal. Calcd. for $C_{16}H_{14}N_2$: C, 82.02; H, 6.02; N, 11.96. Found: C, 82.6; H, 6.21; N, 11.79.

3-Cyano-4-methyl-5-phenyl-2-pyridone (III). The sodio salt of 1-hydroxymethylene-1-phenyl-2 propanone was prepared as described above by reaction of 150 g. (1.12 moles) of phenylpropanone and 150 g. of ethyl formate in the

(33) Melting points are corrected.

(34) *Cf.* M. Orchin and L. W. Butz, *J. Am. Chem. Soc.*, **65**, 2296 (1943), and O. Diels, J. Sielisch, and E. Müller, *Ber.*, **39**, 1328 (1906).

presence of dry sodium methoxide freshly prepared from 28 g. (1.22 g.-atoms) of sodium, in 700 ml. of dry ether. Next day the crude preparation was treated with 85 g. of cyanoacetamide and 900 ml. of reagent methanol, was boiled for 1 hr. to remove the ether, and was then refluxed vigorously for 3 hr. Most of the remaining solvent was distilled, and the chilled residue was treated with a cold solution of 150 ml. of concd. hydrochloric acid in 500 ml. of water. The suspension was kept at 0° for 2 days and the crystals were collected, washed with water, and triturated with methanol. The yield of slightly discolored crystals, m.p. 183–186° dec., was 94 g. (45%). Recrystallization from methanol gave colorless needles, m.p. 190–192° dec.; λ_{max}^{Nujol} 4.48, 6.04 and 6.17 μ; $\lambda_{max}^{C_2H_5OH}$ 237 and 336 mμ (log ϵ 3.85 and 4.11, respectively).

Anal. Calcd. for $C_{13}H_{10}ON_2$: C, 74.3; H, 4.79; N, 13.33. Found: C, 73.8; H, 4.86; N, 13.36.

A virtually quantitative recovery of the compound was obtained when a sample of this pyridone was refluxed with twenty parts of concentrated hydrochloric acid for 3 hr.

3-Cyano-5-phenyl-6-methyl-2-pyridone (IV). A solution of 80 g. (0.495 mole) of 1-hydroxymethylene-1-phenyl-2-propanone and 41 g. (0.49 mole) of cyanoacetamide in 1 l. of methanol was treated with 60 ml. of piperidine. A moderate exothermic effect was noticed, and the solution became deep red. When the solution had cooled nearly to room temperature again (20 min.) it was treated with 60 ml. of glacial acetic acid and allowed to stand at room temperature for 12 days. During this time crystals gradually deposited, and were collected periodically; after each filtration the mother liquor was reduced in volume to the extent of about 10–20% and set aside until more product was obtained. The total yield of methanol washed crystals, m.p. 285–290° dec., was 8 g. (9%). Recrystallization from methanol raised the m.p. to 294–296° dec.; λ_{max}^{Nujol} 4.48 and 6.04 μ; $\lambda_{max}^{C_2H_5OH}$ 248 and 347 (log ϵ 4.18 and 4.00, respectively); $\lambda_{max}^{0.1N\ KOH}$ 264 and 340 (log ϵ 4.19 and 3.98, respectively).

Anal. Calcd. for $C_{13}H_{10}ON_2$: C, 74.27; H, 4.79; N, 13.3. Found: C, 74.25; H, 4.93; N, 12.9.

The compound gave only a very weak greenish ferric chloride test. It was soluble in dilute sodium hydroxide solution and in methanolic piperidine. When the piperidine-catalyzed reaction was carried out under more strenuous conditions in a concentrated solution, the yield of cyanopyridone was lower (*ca.* 2%) and much intractable tar was formed.

An attempt to esterify the nitrile with methanolic hydrogen chloride resulted in incomplete conversion to ester (infrared).

3-Carbiminomethoxy-5-phenyl-6-methyl-2-pyridone (V). A solution of 89 g. (0.55 mole) of 1-hydroxymethylene-1-phenyl-2-propanone and 46 g. (0.547 mole) of cyanoacetamide in 700 ml. of methanol was warmed to 55° and treated first with 45 ml. of pyridine and then with 50 ml. of piperidine, while swirling. The boiling hot solution was allowed to cool down gradually (1 hr.) to room temperature and was left to stand overnight. The next day 100 ml. of glacial acetic acid was added, and the solution was boiled gently on a steam bath for 2 hr. until excess methanol (*ca.* 400 ml.) was removed. During this time crystallization usually began; if not, it was initiated by seeding. The concentrated solution was allowed to stand for several days to ensure complete separation of the product, or alternatively, the crystals were collected in several crops over a period of a week, as for the nitrile. The yield of methanol-washed, colorless crystals, m.p. >220° dec. varied from 25 to 40 g. (18–30%) in a number of runs, and was lowered considerably by any great departure from the conditions stated above. Recrystallization from methanol gave colorless crystals which did not melt sharply but gradually decomposed from 230°; λ_{max}^{Nujol} 3.01, 3.17–3.19, 5.87, and 5.99 μ. The ultraviolet spectrum was similar to that of the corresponding nitrile. The compound gave an orange ferric chloride test.

Anal. Calcd. for $C_{14}H_{14}O_2N_2$: C, 69.4; H, 5.83; N, 11.56. Found: C, 68.7; H, 5.43; N, 11.69.

3-Carbomethoxy-5-phenyl-6-methyl-2-pyridone (VI). When a solution of 36 g. (0.222 mole) of hydroxymethylenephenylpropanone and 26 g. (0.230 mole) of ethyl cyanoacetate in 200 ml. of methanol was treated with 21 ml. of piperidine, an exothermic reaction occurred. When this subsided, the solution was refluxed for 15 min., then cooled, and treated with 40 ml. of glacial acetic acid. Upon standing, the solution began to deposit crystals after 5 days. These were collected on the seventh day and washed with methanol; yield 12.2 g. (22%) of colorless prisms, m.p. 213–219°. Recrystallization from methanol raised the m.p. to 230–232°; λ_{max}^{Nujol} 5.72 and 6.05 μ; $\lambda_{max}^{C_2H_5OH}$ 250 and 346 mμ (log ϵ 4.22 and 4.00, respectively); λ_{max}^{alkali} 246 and 303 mμ (log ϵ 4.04 and 3.85, respectively).

Anal. Calcd. for $C_{14}H_{13}O_2N$: C, 69.12; H, 5.39; N, 5.76. Found: C, 69.16; H, 5.49; N, 5196, 5.60.

When this experiment was repeated, and the solution seeded after addition of acetic acid, the product was obtained on the same day in 9-g. (17%) yield.

5-Phenyl-6-methyl-2-pyridone-3-carboxylic acid (VIII). A mixture of 33 g. of 3-carbiminomethoxy-5-phenyl-6-methyl-2-pyridone and 900 ml. of concd. hydrochloric acid was refluxed for 3 hr. The boiling hot solution was decanted from a small amount of tar and was diluted with an equal volume of cold water. The product was collected and washed with water; yield 28.6 g. (88%) of crystals, m.p. 267–270° dec. which were suitable for further work. Recrystallization from aqueous methanol gave colorless, gleaming flakes, m.p. 269–271° dec.; λ_{max}^{Nujol} 3.20 (broad), 5.81 and 5.88 (doublet), and 6.06 μ; $\lambda_{max}^{C_2H_5OH}$ 246 and 303 mμ (log ϵ 4.05 and 3.80, respectively); λ_{max}^{alkali} 245 and 303 mμ (log ϵ 4.04 and 3.85, respectively).

Anal. Calcd. for $C_{13}H_{11}O_3N$: C, 68.11; H, 4.84; N, 6.11. Found: 68.17; H, 4.82; N, 6.19.

The same compound was obtained by similar acid hydrolysis of both the 3-cyano- and 3-carbethoxypyridones. The acid gave an orange color test with ferric chloride.

The infrared spectra of this acid and all three of its precursors also disclosed weak "zwitterionic" bands in the region 2300–2700 cm.$^{-1}$ and sharp monosubstituted benzene peak in the range 701–707 cm.$^{-1}$

Amides corresponding to 5-phenyl-6-methyl-2-pyridone-3-carboxylic acid (VII). The ester, 3-carbomethoxy-5-phenyl-6-methyl-2-pyridone, reacted spontaneously with *ca.* 50% aqueous solutions of appropriate primary amines to give the following corresponding amides:

(A) *N-Methylamide* formed in brilliant white crystals from methanol, m.p. 316–318° dec.; λ_{max}^{Nujol} 3.11–3.22 (bonded), 5.88 and 6.19 μ; $\lambda_{max}^{C_2H_5OH}$ 246 and 339 mμ (log ϵ 4.25 and 4.02, respectively).

Anal. Calcd. for $C_{14}H_{14}O_2N_2$: C, 69.40; H, 5.83; N, 11.56. Found: C, 69.11; H, 5.83; N, 11.62.

(B) *N-Ethylamide* formed colorless, shiny flakes from methanol, m.p. 249–251°; λ_{max}^{Nujol} 3.22 (bonded), 5.93 and 6.20 μ; $\lambda_{max}^{C_2H_5OH}$ 247 and 337 mμ (log ϵ 4.25 and 4.03, respectively).

Anal. Calcd. for $C_{15}H_{16}O_2N_2$: C, 70.29; H, 6.29; N, 10.93. Found: C, 70.6; H, 6.37; N, 11.3.

(C) *N-(N',N'-Diethylaminoethyl)amide* formed as slightly bluish, brilliant white crystals from aqueous ethanol, m.p. 180–182°; λ_{max}^{Nujol} 3.2 and 5.98 μ.

Anal. Calcd. for $C_{19}H_{25}O_2N_3$: C, 69.70; H, 7.70; N, 12.84. Found: C, 70.1; H, 7.78; N, 13.0.

(D) *N-(N',N'-Diethylaminopropyl)amide* formed as colorless crystals from aqueous alcohol, m.p. 181–182°; λ_{max}^{Nujol} 3.0, 5.92 and 6.08 μ.

Anal. Calcd. for $C_{20}H_{27}O_2N_3$: C, 70.35; H, 7.97; N, 12.31. Found: C, 70.08; H, 7.94; N, 12.44.

(E) *N-(β-Phenylethyl)amide* formed as colorless, shiny crystals from ethyl alcohol, m.p. 248–250°; λ_{max}^{Nujol} 3.0–3.2 (bonded) and 5.89 μ.

Anal. Calcd. for $C_{21}H_{20}O_2N_2$: C, 75.88; H, 6.07; N, 8.43. Found: C, 75.79; H, 6.07; N, 8.33.

(F) *Hydrazide* formed as fine, colorless crystals from ethanol, m.p. > 350°; λ_{max}^{Nujol} 3.03, 5.91 and 6.08 μ

Anal. Calcd. for $C_{13}H_{13}O_2N_3$: C, 64.18; H, 5.39; N, 17.28. Found: C, 64.19; H, 5.35; N, 17.00.

These derivatives, as well as the parent ester and acid, were very resistant to catalytic hydrogenation. The amides and hydrazide resisted hydrolysis with concentrated hydrochloric acid, but in certain cases (*N*-methyl- and *N*-ethylamides) could be hydrolyzed back to the parent acid in the presence of alkali. Attempts to treat the pyridone ester with strong aqueous solutions of secondary amines resulted mainly in hydrolysis to the acid.

3-Carbethoxy-5-phenyl-6-methylpyridine (IX). (A) *2-Chloro-3-carbethoxy-5-phenyl-6-methylpyridine.* The conversion of 3.2 g. of 5-phenyl-6-methyl-2-pyridone-3-carboxylic acid to the corresponding *2-chloro acid chloride* was effected by refluxing with 30 ml. of phosphorus oxychloride containing 5 g. of phosphorus pentachloride, for 1 hr. After distillation of excess reagent on a steam bath (aspirator), the cooled, residual, crude acid chloride was allowed to react with 80 ml. of ethanol. After evaporation of excess alcohol, the residual oil was treated with cold water and extracted with ether. The ether solution was washed with successive portions of potassium carbonate solution and water, and was dried over potassium carbonate. Evaporation of the solvent gave sweet-smelling, brown oil, which did not crystallize.

(B) *Hydrogenation.* The crude product from (A) in 10 ml. of water and 150 ml. of ethanol was shaken under hydrogen (3 atm.) in the presence of 2 g. of 10% palladium-charcoal at room temperature for 2.2 hr. Filtration and evaporation of the alcohol gave an orange gum. This material was partitioned with ether and strong potassium carbonate solution, and the ether solution, after drying, was evaporated. The remaining oil (1.5 g.) had the expected characteristic odor. It did not crystallize, and so a sample was converted to the *picrate;* bright yellow crystals from ethanol, m.p. 147–148.5°; $\lambda_{max}^{C_2H_5OH}$ 218, 322 (shoulders).

Anal. Calcd. for $C_{21}H_{18}O_8N_4$: C, 53.62; H, 3.86; N, 11.91. Found: C, 53.58; H, 3.85; N, 11.78.

This pyridine ester (1 g.) was treated with ethyl oxalate (6 g.) in the presence of sodium methoxide (from 1.3 g. of sodium) in methanol, and the solution was refluxed for 0.5 hr. Evaporation of the solvent, and treatment of the residue with water gave a bright yellow solid which was crystallized from methanol; bright yellow cottony needles, m.p. 173–174°; λ_{max}^{Nujol} 5.75, 5.82, and 6.11 μ; $\lambda_{max}^{C_2H_5OH}$ 223, 284–300, 316 and 343 mμ. Since the material was insoluble in alkali and did not give an immediate ferric chloride test, it is formulated as the *methyl enol ether* of *methyl 3-carbomethoxy-5-phenyl-6-pyridylpyruvate* (compound X).

Anal. Calcd. for $C_{18}H_{17}O_5N$: C, 66.05; H, 5.24; N, 4.28. Found: C, 65.99; H, 5.32; N, 4.50.

Neutralization of the washed aqueous solution from this reaction, and extraction with ether afforded *ca.* 100 mg. of the corresponding *enol;* m.p. 152–153° after recrystallization from methanol; λ_{max}^{Nujol} 3.26 (bonded), 5.78, 5.82, and 6.16 μ. The ultraviolet spectrum was very similar to that of the foregoing compound with maxima at 223, 287, 316, and 343 mμ.

Anal. Calcd. for $C_{17}H_{15}O_5N$: C, 65.17; H, 4.82; N, 4.47. Found: C, 65.43; H, 5.21; N, 4.63.

When these compounds were treated with polyphosphoric acid at 100° for 1 hr., no cyclization products could be isolated, and the material obtained appeared to have lost the pyruvic ester side chain.

Esters (XII) *corresponding to 3-cyano-5-phenyl-6-methyl-2-pyridone-4-carboxylic acid.* A solution of 55.5 g. (0.237 mole) of crude ethyl 2-keto-3-phenyl levulinate and 25 g. (0.298 mole) of cyanoacetamide in 500 ml. of methanol was warmed gently on a steam bath and treated with 27 ml. of piperidine. A mild exothermic effect was noticed, and the solution became deep red. The solution was boiled gently for 10 min., whereupon it became deep green. The cooled solution was treated with 31 ml. of glacial acetic acid and allowed to stand overnight. The next day crystals had begun to form, and separation of additional material was facilitated by evaporating part of the solvent. The product was collected in several crops, washed with methanol, and air dried; yield 31.3 g. (49%) of brownish yellow crystals, m.p. 170–182°. Recrystallization from methanol gave yellow needles, m.p. 182–185°. Analysis of this material indicated that it consisted of a mixture of methyl and ethyl esters.

Anal. Found: C, 67.10; H, 4.74; N, 9.38.

A pure sample of the *methyl ester* was obtained by treating some of the material briefly with acetic anhydride (20 min.), evaporating the excess reagent, and recrystallizing the residue from methanol–ethyl acetate; light yellow needles, m.p. 198–199°; λ_{max}^{Nujol} 3.1–3.2 (bonded), 4.48, 5.74, 6.01 and 6.17 μ; $\lambda_{max}^{C_2H_5OH}$ 229, 244 and 371 mμ (log ϵ 4.11, 3.80 and 4.00, respectively).

Anal. Calcd. for $C_{15}H_{12}O_3N_2$: C, 67.15; H, 4.51; N, 10.44. Found: C, 66.97; H, 4.54; N, 10.66.

The *ethyl ester* was obtained by treating the mixed product with sodium ethoxide in ethanol, followed by acidification to regenerate the pyridone from the sodium salt. The material was collected, washed with water and recrystallized from ethanol; pale yellow crystals, m.p. 165–167°; λ_{max}^{Nujol} 3.20 (bonded), 4.48, 5.76 and 6.08 μ.

Anal. Calcd. for $C_{16}H_{14}O_3N_2$: C, 68.07; H, 5.00; N, 9.92. Found: C, 68.14; H, 5.03; N, 10.10.

When the cyano esters were treated with acetic anhydride at 100° for 1 hr., a compound which appeared to be *acetylimino anhydride* (XIII) was formed; crystallized from acetic anhydride-ethyl acetate, the material consisted of bright yellow needles, m.p. dec. from 195°; λ_{max}^{Nujol} 5.64, 5.82 and 6.01 μ.

Anal. Calcd. for $C_{16}H_{12}O_4N_2$: C, 64.86; H, 4.08; N, 9.46. Found: C, 65.01; H, 4.23; N, 9.44.

The cyano esters responded very poorly in attempts to bring about reaction with ethyl oxalate in the presence of sodium alkoxides, under various conditions. Most of the material was recovered unchanged upon subsequent acidification.

5-Phenyl-6-methyl-2-pyridone-3,4-dicarboxylic acid (XIV). A suspension of 37.5 g. of nitrile ester from the preceding experiment in 1400 ml. of concd. hydrochloric acid was refluxed for 40 min., until the original crystals had dissolved and the product had begun to separate. The suspension was chilled and the diacid was collected and washed with several portions of cold water. The yield of yellow crystals, m.p. 225–230° dec., was 30.5 g. (81%). Recrystallization from aqueous alcohol afforded a colorless sample having the same melting point. The acid was soluble in bicarbonate solution and evolved carbon dioxide when melted; λ_{max}^{Nujol} 3.13–3.15; 5.71 and 5.85 (doublet), and 6.10–6.12 μ.

Anal. Calcd. for $C_{14}H_{11}O_5N$: C, 61.54; H, 4.06· N, 5.13. Found: 61.3; H, 4.14; N, 5.00.

The infrared spectrum of this acid, as well as its various related compounds (see below) also showed a sharp peak in the region of 696–705 cm.$^{-1}$

The corresponding *anhydride XV* was obtained when a sample (1 g.) of the diacid was heated with acetic anhydride (50 ml.) on a steam bath for 1.3 hr. Evaporation of the excess reagent and recrystallization of the material from ethyl acetate gave bright yellow crystals, m.p. 240–243° dec.; λ_{max}^{Nujol} 5.38, 5.56–5.58, 5.96, and 6.02 μ; $\lambda_{max}^{C_2H_5OH}$ 225, 264, and 336 mμ (log ϵ 3.87, 2.91, and 3.99, respectively).

Anal. Calcd. for $C_{14}H_9O_4N$: C, 65.88; H, 3.55; N, 5.49. Found: C, 65.87; H, 3.64; N, 5.39.

A corresponding *methyl acid ester* formed slowly when either the anhydride or the diacid was dissolved in methanol and allowed to stand for several days; yellow crystals from methanol-ethyl acetate, m.p. dec. from 215°; λ_{max}^{Nujol} 3.14–3.15, 5.71 and 5.82–5.85 (doublet), and 6.10–6.13 μ; $\lambda_{max}^{alc.}$ 228 and 326 mμ (log ϵ 4.15 and 4.08, respectively).

Anal. Calcd. for $C_{15}H_{13}O_5N$: C, 62.71; H, 4.56; N, 4.88. Found: C, 62.68; H, 4.28; N, 4.91.

5-Phenyl-6-methyl-2-pyridone-4-carboxylic acid (XVI). A suspension of 2.8 g. of diacid from the preceding experiment (or cyano ester preceding it) in a total of 200 ml. of concd. hydrochloric acid was refluxed for 2.5 hr., until the bright yellow color had faded almost completely. The cooled solution deposited crystals very quickly when a little water was added. These were collected, washed with water, and air dried; 2.1 g. of colorless crystals, m.p. from 270° dec. The purity was improved somewhat by recrystallization from methanol (very sparingly soluble); dec. from 280°; λ_{max}^{Nujol} *ca.* 3.25 (bonded), 5.88–5.97 (broad) and *ca.* 6.14 μ (broad shoulders); $\lambda_{max}^{C_2H_5OH}$ 224, 258, 266 and 325 mμ (log ϵ 3.96, 3.87, 2.81, and 4.05, respectively). These spectra were different from those of the 3-carboxylic acid described above.

Anal. Calcd. for $C_{13}H_{11}O_3N$: C, 68.11; H, 4.84; N, 6.11. Found: C, 68.08: H, 4.99; N, 6.28.

The corresponding *methyl ester* XVIII (R = CH_3) was prepared by refluxing a sample of the acid (0.6 g.) with saturated methanolic hydrogen chloride (250 ml.) for 2 hr. Evaporation of the excess reagent and addition of water gave 0.5 g. of colorless crystals, m.p. 180–182°, raised by recrystallization from ethyl acetate to m.p. 183–185°; λ_{max}^{Nujol} 3.21 (weak, bonded), 5.76, and 6.00–6.10 (doublet).

Anal. Calcd. for $C_{14}H_{13}O_3N$: C, 69.12; H, 5.39; N, 5.76. Found: 68.71; H, 5.43; N, 5.70.

The corresponding *ethyl ester* XVIII (R = C_2H_5) was obtained by reaction of the acid (2.5 g.) with phosphorus oxychloride (35 ml.) and phosphorus pentachloride (5 g.) under reflux for 1 hr., followed by removal of excess reagent and treatment of the residue with ethanol. After the product had been washed with water and recrystallized from ethanol or ethyl acetate, it had a m.p. of 154–155°; λ_{max}^{Nujol} 3.22 (weak, bonded), 5.78, and 6.04–6.13 μ (doublet).

Anal. Calcd. for $C_{15}H_{15}O_3N$: C, 70.02; H, 5.88; N, 5.44; C_2H_5O, 17.5. Found: C, 69.85; H, 5.86; N, 5.42; C_2H_5O, 16.6.

5-Phenyl-6-methyl-2-piperidone-4-carboxylic acid (XVII). A solution of 1 g. of 5-phenyl-6-methyl-2-pyridone-4-carboxylic acid in 150 ml. of glacial acetic acid containing 2 g. of 10% palladium-charcoal was shaken under hydrogen (45 lb.) at 75° for 1.5 hr. Filtration of the catalyst and evaporation of the solvent gave a quantitative yield of crystals, m.p. 178–182°. Recrystallization from ethyl acetate raised the m.p. to 196–197°; λ_{max}^{Nujol} 3.08–3.09, 3.16–3.7, 5.85, and 6.13 μ.

Anal. Calcd. for $C_{13}H_{15}O_3N$: C, 66.93; H, 6.48; N, 6.01. Found: C, 67.16; H, 6.8; N, 6.30, 6.01.

This lactam was sensitive to alcohols and to moisture; when it was treated with wet methanol the melting point rose to 218–220° and the material then appeared to be partly a hydrate of corresponding amino acid or acid ester (λ_{max}^{Nujol} 3.1 broad, 4.0–4.3 and 5.10 broad, 5.85–5.88 and 6.19 μ).

Anal. Found: C, 65.7; H, 8.8; N, 6.0.

The corresponding *methyl ester* was obtained by esterification of the acid lactam (0.7 g.) with saturated methanolic hydrogen chloride (3-hr. reflux). After evaporation of the methanol and treatment with cold water, the resulting colorless solid was recrystallized from ethyl acetate; colorless needles, m.p. 157–159°; λ_{max}^{Nujol} 3.06–3.15 (bonded), 5.75, and 6.02 μ.

Anal. Calcd. for $C_{14}H_{17}O_3N$: C, 67.99; H, 6.93; N, 5.66. Found: C, 68.29; H, 7.08; N, 5.81.

3-Carboxy-5-phenyl-2-pyridone-6-pyruvic acid (XIX; R = H). A suspension of 20 g. of 5-phenyl-6-methyl-2-pyridone-3-carboxylic acid in 65 ml. of oxalyl chloride and 30 ml. of phosphorus oxychloride was refluxed for 40 min., taking care to keep all the solid material in contact with the reagent. The evolution of hydrogen chloride was complete in about 30 min., and dense, dark orange crystals were formed. The cooled suspension was diluted with 100 ml. of dry benzene and the crystals were collected and washed with benzene. This material (24.6 g.), apparently a *phosphorus complex of the diacid chloride*, fumed slowly in moist air. It was ground up in cold water thoroughly, and when the hydrolysis seemed to be complete the product was collected, washed with water and air dried. The yield of crude enol acid was 22.3 g. (85%); bright greenish yellow solid, m.p. dec. from 190°. It was not possible to purify this material by recrystallization. The compound gave a deep green ferric chloride test; λ_{max}^{Nujol} 3.08 (broad; bonded), 5.78 (shoulder), 5.88 and 6.21 μ; $\lambda_{max}^{C_2H_5OH}$ 235–240, 372, 415, and 422 mμ (qualitatively). The infrared spectrum also disclosed a sharp peak at 700 cm.$^{-1}$

The corresponding *diethyl ester* XIX (R = C_2H_5) was obtained in good yield by treating a sample of crude complex, obtained as described above, with absolute ethanol. After the exothermic reaction subsided, the excess alcohol was evaporated, and water was added. The ester was collected, washed with water, and recrystallized from methanol; bright yellow needles, m.p. 168–170°; λ_{max}^{Nujol} 5.79, 5.94, 6.11 (shoulder) and 6.21 μ; $\lambda_{max}^{C_2H_5OH}$ 224, 232, 312, 440, and 450 mμ (log ϵ 4.11, 4.087, 4.10, 4.526, and 4.523, respectively). The infrared spectrum showed an intense peak at 700 cm.$^{-1}$ and little or no evidence of a normal hydroxyl group, and therefore in this compound the enolic group evidently is completely chelated with the nitrogen atom. The compound gave a deep greenish brown ferric chloride test, and was stable.

Anal. Calcd. for $C_{19}H_{19}O_6N$: C, 63.86; H, 5.36; N, 3.92. Found: C, 63.88; H, 5.44; N, 3.73; Cl, 0.

The crude enolic diacid tended to discolor gradually on standing, and therefore was customarily cyclized as soon as possible after preparation. Slight evolution of hydrogen chloride during treatment with concentrated sulfuric acid, as described below, indicated that the material still contained a certain amount of phosphorus halide.

Reaction of 5-phenyl-6-methyl-2-pyridone-3,4-dicarboxylic acid with oxalyl chloride. A suspension of this diacid (13.4 g.) in 40 ml. each of oxalyl chloride and phosphorus oxychloride was refluxed for 45 min. There was copious evolution of hydrogen chloride, and new crystals were formed. The cooled mixture was diluted with about 100 ml. of dry benzene; the product was collected and washed with benzene. There was obtained 10.2 g. of deep red, very dense crystals, m.p. 241–244° dec.; λ_{max}^{Nujol} 5.46, 5.61, 5.76, 5.92, and 6.17 μ; the infrared also showed monosubstituted benzene peak at 705 cm.$^{-1}$ The compound was insoluble in nonhydroxylic solvents and could not be recrystallized without alteration. It did not contain chlorine. Solutions of the compound in alcohol became deep blue when diluted with water.

Anal. Calcd. for $C_{16}H_7O_6N$: C, 62.14; H, 2.28; N, 4.53. Found: C, 61.57; H, 2.37; N, 4.32, 4.24, 3.89.

In view of the spectra, analytical data, and certain other properties (see below) of this compound, it is formulated as *XX*, the *cyclic anhydride and lactam* corresponding to *3,4-dicarboxy-5-phenyl-2-pyridone-6-pyruvic acid.* When the red crystals were warmed with methanol, an orange, poorly characterized, unstable substance, evidently an enolic acid ester, was formed; this material gave a deep purple ferric chloride test and showed bands at 3.08 (broad), 5.71, 5.79, 5.96, and 6.17 μ, as well as at 706 cm.$^{-1}$, in the infrared. Similar ferrichloride-positive materials were obtained when the lactam anhydride was treated with water or aqueous acids. Good analytical results could not be obtained with any of these products, and none of them had sharp melting points nor could they be purified successfully by recrystallization. Ultraviolet spectra of these materials, showing strong peaks at *ca.* 225, 270–290, 340, and 410 mμ, were similar to those observed with the pyruvic derivatives of the related monoacid and ester.

Attempts to cyclize the anhydride lactam and corresponding derivatives with concentrated sulfuric acid led to decomposition and partial formation of water-soluble products; the remaining solid still gave a ferric chloride test.

3-Hydroxybenzo[f]quinoline-2,6-dicarboxylic acid (XXI). A mixture of 22.6 g. of crude 3-carboxy-5-phenyl-2-pyridone-

6-pyruvic acid and 250 ml. of concd. sulfuric acid was stirred until the solid material had all dissolved (3–4 hr.). A moderate, slow rise in temperature (*to ca.* 45°) was observed initially, and a small amount of hydrogen chloride was released. The resulting deep red solution was allowed to stand at room temperature for 2 days. It was then poured over 2 kg. of chopped ice, with stirring. The mixture was stirred or allowed to stand until the ice melted and the gelatinous solid became finely divided crystals which could easily be filtered. The product was collected, washed with several portions of water, and was triturated with methanol to remove water and soluble impurities. The yield of ferric chloride–negative yellow crystals, m.p. >360°, was 15.8 g. (74%). A pure sample was secured by recrystallization from methanol (very sparingly soluble); greenish yellow needles, m.p. >360°; λ_{max}^{Nujol} 3.19–3.3 (broad, bonded), 5.84 and 6.08 μ; $\lambda_{max}^{C_2H_5OH}$ 243, 267, 336, 385, and 398 mμ (log ϵ 4.78, 4.12, 3.926, 4.08, and 4.09, respectively). The compound appeared from analysis to be slightly solvated, even after drying at 80° *in vacuo*.

Anal. Calcd. for $C_{15}H_9O_5N$: C, 63.61; H, 3.20; N, 4.95. Found: C, 62.66; H, 3.29; H, 5.04.

The corresponding *diethyl ester* was obtained as follows: the sulfuric acid–cyclization mixture (30 ml.) from another experiment, in which 2 g. of pyridone–pyruvic acid had been employed, was poured into 150 ml. of absolute ethanol, and the solution was heated on a steam bath for 0.5 hr. Isolation of the neutral product and recrystallization of that material (gummy crystals) from ethanol gave (0.5 g.) greenish yellow needles, m.p. 209–211°; λ_{max}^{Nujol} 5.80, 5.88, 6.01, and 6.16 μ; the 700-cm.$^{-1}$ peak was absent; $\lambda_{max}^{C_2H_5OH}$ 221, 243, 265, 327, and 393 mμ (log ϵ 4.50, 4.79, 4.30, 3.98, and 4.01, respectively). The ferric chloride test was negative.

Anal. Calcd. for $C_{19}H_{17}O_5N$: C, 67.25; H, 5.05; N, 4.13. Found: C, 67.44; H, 5.04; N, 4.17.

The corresponding *bis(N-ethyl)amide* was prepared by conversion of a sample (1.2 g.) of the diacid to the diacid chloride with thionyl chloride (100 ml.; refluxed for 0.6 hr.) followed by removal of the thionyl chloride and treatment with ethylamine. Recrystallization from ethanol and ethyl acetate gave pale yellow crystals, m.p. >360°; λ_{max}^{Nujol} 3.07, 5.96, and 6.06 μ; $\lambda_{max}^{C_2H_5OH}$ 242, 258, 334, 383 and 394 mμ (qualitatively, because of extremely low solubility).

Anal. Calcd. for $C_{19}H_{19}O_3N_3$: C, 67.64; H, 5.68; N, 12.46. Found: C, 67.36; H, 5.75; N, 12.40.

8-Hydroxy-8-nitro-benzo[f]quinoline-2,6-dicarboxylic acid (XXV). A suspension of 5.1 g. of 3-hydroxybenzo[*f*]quinoline-2,6-dicarboxylic acid in 100 ml. of concd. nitric acid was refluxed gently for 10 min., whereupon the crystals dissolved and a small amount of finely-divided, bright yellow crystals separated. The warm solution was filtered to remove this precipitate (1.3 g.), which proved to be an isomeric mononitroderivative, possibly the 10-nitro compound. The clear nitric acid solution was diluted with cold water. The product was collected and washed with water; 4.4 g. (75%) bright yellow crystals, m.p. dec. from 280°; λ_{max}^{Nujol} 5.80–5.85, 6.13–6.17, and 6.54–6.58 μ; $\lambda_{max}^{C_2H_5OH}$ 240, 250, 314, 377, and 394 mμ (qualitative).

Anal. Calcd. for $C_{15}H_{10}O_8N_2$: C, 52.03; H, 2.91; N, 8.09. Found: C, 52.24; H, 2.94; N, 8.7.

Neither this compound nor the byproduct could be recrystallized satisfactorily from any solvent.

8-Hydroxy-8-aminobenzo[f]quinoline-2,6-dicarboxylic acid (XXVI). A solution of 9.2 g. of the 8-nitro compound from the preceding experiment in 350 ml. of water and 9 ml. of concd. ammonium hydroxide, containing 5 g. of 10% palladium-charcoal, was shaken under hydrogen (45 lb.). A pressure drop of 7 lb. was observed (4-l. hydrogen reserve tank) in 20 min., after which there was no further uptake. The filtered solution was treated with 35 ml. of concd. hydrochloric acid. The orange, finely divided solid was collected, washed with water and air dried (8 g.). All attempts to recrystallize this extremely insoluble compound (m.p. >360°) were unsuccessful, and it appeared to be hydrated. A fairly pure sample was secured by dissolving some of the material in concentrated sulfuric acid and reprecipitating it with water.

Anal. Calcd. for $C_{15}H_{10}O_8N_2$: C, 60.40; H, 3.38; N, 9.39. Found: C, 60.0; H, 3.59; N, 9.8.

The infrared spectrum (Nujol) had very broad bands in the NH, OH, and "zwitterion" regions and broad peaks at 5.75–5.82 and 6.12–6.14 μ.

The *N-acetyl* derivative, also extremely insoluble and having a m.p. >350°, was prepared by refluxing the amino compound with acetic anhydride for 5 hr.; bright orange crystals, λ_{max}^{Nujol} 3.16 (broad), 5.79 and 6.03 μ (broad).

Anal. Calcd. for $C_{17}H_{12}O_9N_2$: C, 60.00; H, 3.55; N, 8.23. Found: C, 60.20; H, 3.74; N, 8.36.

The by-product, presumably the 10-nitro isomer, obtained in the preceding nitration experiment, was also reduced in dilute ammonia solution in the presence of palladium-charcoal, according to the same procedure. In this case also there was no lactam formation: acidification of the filtered solution after hydrogenation gave an amino acid (quantitative yield) which was recrystallized from methanol; very sparingly soluble, red-orange crystals, m.p. >360°. The infrared spectrum showed very broad bands in the NH, OH, and zwitterionic regions, and peaks at 5.79, 5.87 (shoulder), and 6.14 μ (broad).

Anal. Calcd. for $C_{15}H_{10}O_8N_2$: C, 60.40; H, 3.38; N, 9.39. Found: C, 60.30; H, 3.45; N, 10.1.

Esters (XXIII) *of 3-chlorobenzo[f]quinoline-2,6-dicarboxylic acid.* Derivatives of the 3-chloro acid were always obtained by first preparing the corresponding chloro acid chloride XXII, as follows: A mixture of 20 g. of 3-hydroxybenzo[*f*]quinoline-2,6-dicarboxylic acid, 50 g. of phosphorus pentachloride, and 200 ml. of phosphorus oxychloride was swirled and warmed gently until the solid materials dissolved and the copious evolution of hydrogen chloride was finished (*ca.* 0.5 hr.) and the solution was then refluxed for 2 hr. The excess phosphorus oxychloride was distilled on a steam bath under water-pump vacuum. The residual, crude material was used immediately in further work.

Dimethyl ester. The crude acid chloride preparation obtained as described above was chilled in ice, and 250 ml. of reagent methanol was added. The flask was swirled briskly and the temperature of the reaction was kept below 45° by occasional brief immersion in an ice bath. When the reaction was complete (*ca.* 5 min.) the crystalline suspension was kept at 0° for 20–30 min. The product was collected, was washed free of syrupy material with methanol, and dried. The yield of yellow crystals, m.p. 163–168° dec., was 16.5 g. (70%). This material was suitable for nitration and borohydride reduction experiments, although it was contaminated with a small amount of phosphorus halide which could not be removed by recrystallization. In order to obtain a pure sample, the crystals were shaken with ethyl acetate and potassium carbonate solution; the ethyl acetate solution was dried and evaporated, and the residue was recrystallized from ethyl acetate; pale yellow needles, m.p. 186–188°; λ_{max}^{Nujol} 5.79 μ; $\lambda_{max}^{C_2H_5OH}$ 239, 273, and 320 mμ (log ϵ 4.65, 4.44, and 3.96, respectively).

Anal. Calcd. for $C_{17}H_{12}O_4NCl$: C, 61.92; H, 3.67; N, 4.25. Found: C, 61.99; H, 3.69; N, 4.44.

The mother liquor from this preparation did not give any more chloro ester when kept at 0° for several days, but instead deposited *ca.* 1 g. of yellow crystals, m.p. 255–260°, which appeared to be impure 3-hydroxy dimethyl ester.

Diethyl ester. Reaction of crude acid chloride with ethanol under the same conditions as described above gave (65%) yellow crystals, m.p. *ca.* 165–170°. After treatment with potassium carbonate solution and recrystallization from ethyl acetate there were obtained pale yellow crystals, m.p. 177–178°; λ_{max}^{Nujol} 5.76–5.82 μ (sharp twin peaks); $\lambda_{max}^{C_2H_5OH}$ 239, 273, and 317 mμ (log ϵ 4.60, 4.41, and 3.95, respectively).

Anal. Calcd. for $C_{19}H_{16}O_4NCl$: C, 63.78; H, 4.51; N, 3.92. Found: C, 63.77; H, 4.62; N, 3.94.

The mother liquor from this preparation, when kept at 0° for several days, deposited (20%) yellow crystals of 2,6-dicarbethoxy-3-hydroxybenzo[f]quinoline; recrystallization from ethanol gave yellow crystals, m.p. 207–209°, undepressed upon admixture with the compound prepared as described above. The infrared spectra of the two samples were identical.

The chloro esters were responsive to aqueous or alcoholic acids and bases, and at elevated temperature in the presence of such reagents were hydrolyzed back to the original hydroxy diacid.

Amides (XXIV) *from 3-chlorobenzo[f]quinoline-2,6-dicarboxylic acid chloride.* By reaction of the crude chloro acid chloride (see preceding experiment) with appropriate anhydrous amines, the following derivatives were obtained.

3-Dimethylamino-N,N,N',N'-tetramethylbenzo[f]quinoline-2,6-dicarboxamide was recrystallized from ethyl acetate; pale yellow crystals, m.p. 228–230°; λ_{max}^{Nujol} 6.12 μ (shoulder at 6.15 μ), and 6.29 μ. The compound was soluble in dilute acids.

Anal. Calcd. for $C_{21}H_{24}O_2N_4$: C, 69.21; H, 6.64; N, 15.38. Found: C, 68.8; H, 6.81; N, 15.12, Cl, 0.

3-Pyrrolidino-2,6-bispyrrolidinocarbonylbenzo[f]quinoline was recrystallized from ethyl acetate; pale yellow crystals, m.p. 235–237°; soluble in dilute acid; λ_{max}^{Nujol} 6.12–6.16 and 6.26 μ.

Anal. Calcd. for $C_{27}H_{30}O_2N_4$: C, 73.27; H, 6.83; N, 12.66. Found: C, 72.95; H, 6.98; N, 12.61.

3-Piperidino-2,6-bispiperidinocarbonylbenzo[f]quinoline was recrystallized from ethyl acetate; colorless crystals, m.p. 196–197.5°; λ_{max}^{Nujol} 6.14 and 6.25 μ.

Anal. Calcd. for $C_{30}H_{36}O_2N_4$: C, 74.35; H, 7.49; N, 11.56. Found: C, 74.17; H, 7.63; N, 11.56.

3-Ethylamino-N,N'-diethylbenzo[f]quinoline-2,6-dicarboxamide was recrystallized from ethyl acetate; yellow crystals, m.p. 300–302° dec.; λ_{max}^{Nujol} 3.03 and 6.12 μ.

Anal. Calcd. for $C_{21}H_{24}O_2N_4$: C, 69.21; H, 6.64; N, 15.38. Found: C, 68.8; H, 6.83; N, 15.37.

3-Chloro-N,N,N',N'-tetraethylbenzo[f]quinoline-2,6-dicarboxamide was obtained when the chloro acid chloride was treated with an excess of 1:3 diethylamine in alcohol. After evaporation of the reagent and addition of water, the amide was extracted with ether; the ether solution was washed with water and dried over potassium carbonate, and the residue after evaporation was recrystallized from cyclohexane–ethyl acetate; colorless crystals, m.p. 179–181°; λ_{max}^{Nujol} 6.11–6.16 (sharp twin) and 6.28 μ. The compound was insoluble in dilute acids.

Anal. Calcd. for $C_{22}H_{28}O_2N_3Cl$: C, 67.06; H, 6.36; N, 10.20; Cl, 8.61. Found: C, 66.84; H, 6.45; N, 10.02; Cl, 8.3.

Attempts to reduce this compound with sodium borohydride in methanol were not successful.

Diethyl benzo[f]quinoline-2,6-dicarboxylate (XXXIII. R = C_2H_5). A solution of 1.8 g. of diethyl 3-chlorobenzo[f]-quinoline-2,6-dicarboxylate in 150 ml. of ethanol was treated with a slurry of 2.5 g. of 10% palladium-charcoal in 80 ml. of water. The mixture was shaken under (45 lb.) hydrogen at room temperature for 3 hr. Evaporation of the filtered solution gave a brown, oily residue which was dissolved in ether and shaken with potassium carbonate solution. Evaporation of the dried (potassium carbonate) organic layer and careful trituration of the residual material with ether afforded *ca.* 0.8 g. of yellow solid, which was purified by recrystallization from methanol: pale yellow crystals, m.p. 96–98°; λ_{max}^{Nujol} 5.83 and 6.21 μ; $\lambda_{max}^{C_2H_5OH}$ 232–238, 265, 272, and 314–320 mμ (log ϵ 4.62–4.63, 4.30, 4.28, and 3.99, respectively).

Anal. Calcd. for $C_{19}H_{17}O_4N$: C, 70.57; H, 5.30; N, 4.33. Found: C, 70.61; H, 5.54; N, 4.38.

The low solubility of the starting material in ethanol precluded carrying out this experiment on a larger scale. The results described above were difficult to reproduce even when the same conditions were employed, and in another run a different compound was formed, as described in the next experiment.

Attempts to hydrogenate the chlorodimethyl ester in a similar manner were unsuccessful because of the insolubility of the material.

Diethyl 1,4-dihydrobenzo[f]quinoline-2,6-dicarboxylate (XXXII. R = R' = C_2H_5). (A) A suspension of 5 g. of diethyl 3-chlorobenzo[f]quinoline-2,6-dicarboxylate in ethanol (*ca.* 100 ml.) was treated with sodium borohydride in small portions, with stirring, until there was no further exothermic, effervescent reaction. Additional sodium borohydride (*ca.* 5 g.) was then added, and the mixture was boiled down on a steam cone (1 hr.) to a small volume. Dilution of the cooled residue with water afforded a bright yellow solid, which was collected, washed with water, and air dried. This material (3 g.) was contaminated with inorganic salts. Repeated recrystallization from ethanol and then from methanol afforded bright yellow flakes, m.p. 157–159°; λ_{max}^{Nujol} 3.04 (strong), 5.86, and 6.07 μ (intense), identical with the spectrum of material obtained in (B).

Anal. Found: C, 69.81; H, 5.83; N, 4.43.

(B) Catalytic hydrogenation of 1.8 g. of chlorodiethyl ester in the presence of 2.5 g. of 10% palladium-charcoal in 80 ml. each of water and ethanol, at 50° for 1.5 hr. gave, after evaporation and treatment with potassium carbonate, 0.3 g. of bright yellow crystals, m.p. 152–157°. Recrystallization from methanol afforded a sample having a m.p. of 159–161°; λ_{max}^{Nujol} as in (A); $\lambda_{max}^{C_2H_5OH}$ 228, 294, 333, 346, and 389 mμ (log ϵ 4.91, 4.56, 4.18, 4.30, and 3.64, respectively). The compound appeared to decompose in the presence of hydrochloric acid, and was not completely soluble.

Anal. Calcd. for $C_{19}H_{19}O_4N$: C, 70.14; H, 5.89; N, 4.31. Found: C, 70.12; H, 5.94; N, 4.26.

When the chlorodiethyl ester was reduced with sodium borohydride in the same manner as described above, with the exception that methanol was used in place of ethanol, a *dihydro methylethyl ester* (XXXII. R = C_2H_5; R' = CH_3) was obtained. Recrystallization from methanol to constant melting point gave bright yellow crystals, m.p. 182–185°; λ_{max}^{Nujol} 3.05, 5.83–5.85 and 6.08 μ; the ultraviolet spectrum was virtually the same as that of the preceding compound, with maxima at 229, 296, 329, and 347 mμ.

Anal. Calcd. for $C_{18}H_{17}O_4N$: C, 69.44; H, 5.50; N, 4.50. Found: C, 69.59; H, 5.39; N, 4.58.

Dimethyl 1,4-dihydrobenzo[f]quinoline-2,6-dicarboxylate (XXXII. R = R' = CH_3). Reduction of 10 g. of dimethyl 3-chlorobenzo[f]quinoline-2,6-dicarboxylate with sodium borohydride in methanol by the same procedure as described in the preceding experiment, and subsequent dilution of the cooled, concentrated reaction mixture with water, gave bright yellow crystals; the yield of water-washed, air-dried, crude material was 4.5 g. Trituration with methanol afforded 3.7 g. (37%) m.p. 205–215° dec. Recrystallization from methanol gave a low, variable recovery of pure material, m.p. 215–218° dec.; λ_{max}^{Nujol} 3.01, 3.05, (intense), 5.80, 5.92, and 6.08 μ; the ultraviolet spectrum was very similar to that of the preceding dihydroethyl ester, with maxima at 228, 294, 333, 347, and 391 mμ.

Anal. Calcd. for $C_{17}H_{15}O_4N$: C, 68.67; H, 5.08; N, 4.71. Found: C, 68.9; H, 5.08; N, 4.74.

This compound did not dissolve in hydrochloric acid but was changed into an orange substance.

Dimethyl benzo[f]quinoline-2,6-dicarboxylate (XXXIII. R = CH_3). A suspension of 3.0 g. of triturated dihydro ester from the preceding experiment and 2 g. of 10% palladium-charcoal in 350 ml. of xylene was distilled for 5 min. to remove traces of water and was refluxed vigorously for 1 hr. Filtration of the boiling hot solution, evaporation of the xylene, and trituration of the crystals with a small quantity of methanol afforded 2.0 g. of product, m.p. 145–147°. Recrystallization from methanol gave very pale yellow needles, m.p. 148–150°; λ_{max}^{Nujol} 5.75–5.80 (intense, sharp twin) and 6.20–6 24 (mod., sharp twin); $\lambda_{max}^{C_2H_5OH}$ 224, 238, 266, 321, and 360–366 mμ (log ϵ 4.55, 4.62, 4.31, 4.01, and 3.606, respectively).

Anal. Calcd. for $C_{17}H_{13}O_4N$: C, 69.14; H, 4.44; N, 4.74. Found: C, 69.17; H, 4.50; N, 4.89.

N,N'-Di(β-phenylethyl)benzo[f]quinoline-2,6-dicarboxamide. (A) Crude 3-chlorobenzo[*f*]quinoline-2,6-dicarboxylic acid chloride, prepared as in preceding experiments, was treated with excess β-phenylethylamine. After evaporation of excess reagent, the chlorodiamide was isolated by addition of water, filtration of the gummy crystals, and trituration with ethyl acetate; the crude product had m.p. *ca.* 190° dec.

(B) The solid (4 g.) from (A) was suspended in methanol and treated with sodium borohydride in portions until spontaneous reaction ceased; after addition of *ca.* 5 g. more reagent, the mixture was heated on a steam bath for 0.3 hr. The concentrated suspension was diluted with water and the product was extracted with ethyl acetate–ether. Evaporation of the dried organic solution gave a gummy solid which was used forthwith in the next step.

(C) The crude product from (B) in 350 ml. of xylene, together with 2.5 g. of 10% palladium-charcoal, was refluxed for 1 hr. Evaporation of the filtered (hot) solution gave 0.3 g. of yellow crystals; recrystallization from ethyl acetate afforded yellow needles, m.p. 217–219°; λ_{max}^{Nujol} 3.05 and 6.12 μ.

Anal. Calcd. for $C_{31}H_{27}O_2N_3$: C, 78.62; H, 5.75; N, 8.87. Found: C, 78.93; H, 6.04; N, 9.21.

Hexa- or octahydrobenzo[f]quinoline-2,6-dicarboxylic acid dihydrazide (XXXI). A suspension of 7.5 g. of diethyl 3-chlorobenzo[*f*]quinoline-2,6-dicarboxylate and 8 g. of 10% palladium-charcoal in 300 ml. of ethanol and 50 ml. of water was shaken under hydrogen (45 lb.) at 70°. A pressure drop of 7 lb. (4-l. hydrogen reserve tank) took place gradually during a 5.5-hr. period. The cooled, filtered solution was colorless initially, but soon became dark colored upon exposure to air. The solvent was distilled and the dark residue was shaken with ether and potassium carbonate solution. The dried ether solution was evaporated; the remaining oil (6.2 g.) did not crystallize. It was taken up in 30 ml. of anhydrous hydrazine, and the solution was refluxed for 3 hr. The cooled solution was diluted with *ca.* 200 ml. of water, was filtered to remove some insoluble residue, and was kept at 0° for several days, whereupon platelets separated gradually. The product was collected, washed with water, triturated with ethanol, and air dried; yield, 4 g., slightly discolored crystals, m.p. dec. from 240°. A sample, recrystallized from ethanol, did not melt sharply but decomposed gradually from 255°; λ_{max}^{Nujol} 3.06 (broad, intense), 5.88 (mod.), and 6.06–6.30 (multiple, intense peaks); $\lambda_{max}^{C_2H_5OH}$ *ca.* 250 (shoulder) and 303 mμ (shifted to 296 mμ in acid solution). The material appeared to be a hemihydrate.

Anal. Calcd. for $C_{15}H_{19}O_2N_5 \cdot 1/2\ H_2O$: C, 58.05; H, 6.50; N, 22.57. Found: C, 58.86; H, 6.69; N, 22.45.

This compound and the crude ester preceding it were unstable in the presence of acids.

Esters (XXVII) *of 3-chloro-7-nitrobenzo[f]quinoline-2,6-dicarboxylic acid.* (A) *Ethyl ester.* A sample (5.0 g.) of diethyl 3-chlorobenzo[*f*]quinoline-2,6-dicarboxylate was treated with 40 ml. of ice-cold, 90% nitric acid while stirring, and the solution which immediately resulted was kept at *ca.* 15° by brief immersion in an ice bath during the period of exothermic reaction (5 min.). The nitric acid solution was poured into 500 ml. of ice and water, while stirring. The crystals were collected, washed with several portions of water, pressed dry, and immediately triturated with warm ethanol. When this was done properly, the material became gummy at first, and then the more soluble component of the mixture dissolved, leaving clean, pale yellow crystals, which were collected, washed with enough ethanol to remove remaining oily material, and air dried; the yield of material, m.p. 175–185°, was 4.3 g. (77%). Recrystallization from ethanol afforded very pale yellow, tiny crystals, m.p. 192–194°; λ_{max}^{Nujol} 5.72 and 5.82 (sharp, intense twin), 6.20 and 6.49 μ.

Anal. Calcd. for $C_{19}H_{15}O_6N_2Cl$: C, 56.65; H, 3.75; N, 6.96; Cl, 8.80. Found: C, 56.38; H, 3.77; N, 7.02; Cl, 8.96.

(B) *Methyl ester.* Nitration of 12.5 g. of dimethyl 3-chlorobenzo[*f*]quinoline-2,6-dicarboxylate with 115 ml. of 90% nitric acid was carried out as in (A) except that the nitric acid solution was allowed to stand and warm gradually to *ca.* 20° for 9 min. after the period of slightly exothermic reaction. The product was isolated as in (A), using methanol instead of ethanol in triturating the moist, crude crystals. The yield of triturated, air-dry material, m.p. 205–214° dec., was 13.3 g. (94%). Recrystallization from ethyl acetate gave very pale yellow crystals, m.p. 229–231° dec.; λ_{max}^{Nujol} 5.72 and 5.81 (sharp, intense twin), 6.21 and 6.49 μ.

Anal. Calcd. for $C_{17}H_{11}O_6N_2Cl$: C, 54.48; H, 2.96; N, 7.48; Cl, 9.46. Found: C, 54.9; H, 3.2; N, 7.41; Cl, 9.6.

Attempts to reduce these nitrochloro esters with sodium borohydride gave intractable solid materials having a red or orange color.

Dimethyl 7-nitrobenzo[f]quinoline-2,6-dicarboxylate (XXXIV. R = CH_3). Nitration of 2.0 g. of dimethyl benzo[*f*]quinoline-2,6-dicarboxylate with 35 ml. of 90% nitric acid was carried out as in the preceding experiments, the deep blue-green solution being swirled in an ice bath until (moderately exothermic) reaction was complete and then allowed to stand for 6 min. After hydrolysis (ice water) and trituration of the solid with methanol, there was obtained 1.8 g. (80%) of light-yellow crystals, m.p. 191–197° dec. Recrystallization from ethyl acetate raised the m.p. to 202–204° dec.; λ_{max}^{Nujol} 5.77–5.82 (intense twin), 6.20–6.24 (mod., sharp twin) and 6.52 μ; $\lambda_{max}^{C_2H_5OH}$ 220, 241, 246–253, 307–312, and 353 mμ (log ε 4.56, 4.54, 4.53–4.52, 4.16 and 3.58, respectively).

Anal. Calcd. for $C_{17}H_{12}O_6N_2$: C, 60.00; H, 3.55; N, 8.23. Found: C, 59.86; H, 3.66; N, 8.5.

2-Carbomethoxy-3-chloro-7-aminobenzo[f]quinoline-6-carboxylic acid lactam (XXVIII. R = CH_3). A suspension of 6.4 g. of dimethyl 3-chloro-7-nitrobenzo[*f*]quinoline-2,6-dicarboxylate and 2 g. of 10% palladium-charcoal in 400 ml. of glacial acetic acid was shaken under hydrogen (45 lb.) at 60–70° for 0.5 hr., until the (fairly rapid) pressure drop (4–5 lb.) indicated that approximately 3 moles of hydrogen had been consumed. The hydrogenation was interrupted at this point; the suspension was heated to 100° and filtered as rapidly as possible, and the catalyst was washed with several portions of acetic acid and ethyl acetate. Evaporation of the solvents, and trituration of the partly crystalline, red residue with methanol, gave 2.4 g. (45%), of orange crystals m.p. 287–291° dec. The compound was very sparingly soluble in ordinary solvents. It dissolved partly in, but also appeared to undergo reactions with, hot methanol, and the recrystallized material had a m.p. of 301–302.5° dec. Better results were obtained by recrystallization from ethyl acetate: bright yellow, long needles, m.p. 304–306° dec.; λ_{max}^{Nujol} 3.16–3.26 (mod., broad doublet), 5.74 (mod.) (ester) and 5.82 (intense) (lactam) 6.14, 6.19, and 6.28 μ; also sharp peaks at 762 and 787 cm.$^{-1}$; $\lambda_{max}^{C_2H_5OH}$ 220–228, 235–243, 249, 294, 306, 357, 377, and 404 mμ (log ε 4.50, 4.54–4.55, 4.30, 4.28, 3.34, 3.43, and 3.48, respectively).

Anal. Calcd. for $C_{16}H_9O_3N_2Cl$: C, 61.45; H, 2.90; N, 8.96; Cl, 11.34. Found: C, 61.47; H, 3.01; N, 9.15; Cl, 11.6.

Many attempts were made to dechlorinate this compound by hydrogenation under mild conditions in the presence of nickel, platinum, and palladium catalysts in various solvents and in dilute aqueous or alcoholic alkali. In every case either the starting material was recovered or else chlorine-containing, poorly crystallized materials of doubtful composition were obtained.

For comparison with this compound and others described below, the infrared spectrum of naphthostyril was secured; λ_{max}^{Nujol} 3.13 (mod.; broad), 5.76 (intense, sharp), and 5.97–6.05 μ (mod., sharp twin); $\lambda_{max}^{CHCl_3}$ 2.89, 3.11, 5.82 (very intense, with shoulder at 5.79), and 6.05 μ (mod., sharp). A characteristic sharp, intense peak was also observed at 768 cm.$^{-1}$ in the Nujol spectrum.

1,2-Dihydro-2-carbethoxy-3-oxo-7-aminobenzo[f]quinoline-6-carboxylic acid lactam (XXIX. R = C_2H_5). A suspension of 2.1 g. of diethyl 3-chloro-7-nitrobenzo[*f*]quinoline-2,6-dicarboxylate and 3 g. of 10% palladium-charcoal in 150 ml. of glacial acetic acid was shaken under hydrogen (45 lb.) at 80° for 1 hr. Absorption of hydrogen took place in two stages, partly (3 moles) at room temperature and the remainder (*ca.* 1 mole) at the elevated temperature. Evaporation of the filtered solution and trituration of the partly crystalline residue (ethanol) gave 0.4 g. of yellow crystals, m.p. *ca.* 290° dec. After further treatment of this material with dilute sodium bicarbonate solution and recrystallization from ethanol, there were obtained shiny greenish yellow crystals, m.p. 294–296° dec.; λ_{max}^{Nujol} 3.13, 5.78 (ester), 5.98 (amide) and 6.08 μ, as well as a sharp peak at 768 cm.$^{-1}$; $\lambda_{max}^{C_2H_5OH}$ 255, 278, 292, 304, and 370 mμ (log ϵ 4.635, 3.81, 3.845, 3.70, and 3.81, respectively).

Anal. Calcd. for $C_{17}H_{14}O_4N_2$: C, 65.80; H, 4.55; N, 9.03. Found: C, 65.79; H, 4.59; N, 8.95.

1,2,3,4,4a,5,6,10b-Octahydro-2-carbethoxy-7-aminobenzo[f]quinoline-6-carboxylic acid lactam (XXX). A mixture of 4.2 g. of diethyl 3-chloro-7-nitrobenzo(*f*)quinoline-2,6-dicarboxylate, 6 g. of 10% palladium-charcoal, and 400 ml. of ethanol was shaken under hydrogen (45 lb.). When uptake of 4 moles of hydrogen was complete (15 min.) the temperature was raised to 75° and shaking was continued. Additional hydrogen (3.5 moles) was consumed gradually (3 hr.) and after that the absorption of hydrogen was negligible. Evaporation of the filtered solution, treatment of the residue with cold, dilute sodium bicarbonate solution gave semisolid, brown material which was extracted with 2 l. of ether. The ether solution was dried (potassium carbonate) and evaporated. The remaining oil (1.6 g.) crystallized partly in the presence of a small amount of ethanol, and the triturated crystals (0.5 g.) had a m.p. of 218–225°. Recrystallization from ethanol afforded light greenish yellow crystals, m.p. 232–234° (sinters at 223°); λ_{max}^{Nujol} 2.96 (strong), 5.83–5.94 (intense, sharp doublet) and 6.17 μ; these peaks were shifted to 2.91, 5.77–5.90, and 6.18 μ, respectively, in chloroform; $\lambda_{max}^{C_2H_5OH}$ 236, 319, and 338 mμ (log ϵ 4.33, 3.34 and 3.47, respectively). The compound appeared to be unstable; a marked change in the infrared spectrum occurred upon drying a sample of the compound at 80°, although the melting point and analytical values did not change appreciably.

Anal. Calcd. for $C_{17}H_{20}O_3N_2$: C, 67.98; H, 6.71; N, 9.33. Found: C, 67.91; H, 6.76; N, 9.36.

Other hydrogenations of the ethyl and methyl chloronitro diesters in the presence of palladium, in addition to this experiment and the two preceding it, were carried out using various solvents and temperatures, but they did not lead to conclusive results.

2-Carbomethoxy-7-aminobenzo[f]quinoline-6-carboxylic acid lactam (XXXV. R = CH_3). (A) To a solution of 1.8 g. of dimethyl 7-nitrobenzo[*f*]quinoline-2,6-dicarboxylate in 300 ml. of glacial acetic acid was added 1 g. of 10% palladium-charcoal. The mixture was shaken under hydrogen (45 lb.) at room temperature for 16 min. The filtered solution was evaporated, and the crystals which emerged were triturated with methanol twice; there was obtained 0.9 g. (61%) of golden yellow crystals, m.p. 294–295.5° dec. Recrystallization from methanol gave bright yellow, tiny needles, m.p. 301–302° dec. Another recrystallization from methanol raised the m.p. to 304–305° dec.

Anal. Calcd. for $C_{16}H_{10}O_3N_2$: C, 69.06; H, 3.62; N, 10.07. Found: C, 69.04; H, 3.78; N, 10.00.

(B) A sample (0.3 g.) of the methanol-triturated crystals from (A) was placed in 250 ml. of xylene with 0.5 g. of 10% palladium-charcoal. The mixture was refluxed for 0.5 hr., and filtered while boiling hot; the solution was evaporated and the crystals were recrystallized from methanol. This was the purest sample of the substance which could be obtained; silky, golden yellow needles, m.p. 305–306° λ_{max}^{Nujol} 3.18, 3.25, 3.31 (shoulders); 5.80 and 5.84 (very intense, sharp twin), 6.13 (mod., very sharp) and 6.20 μ; there was also a sharp peak at 790 cm.$^{-1}$.

Anal. Found: C, 69.04· H, 3.68; N, 10.06.

The mixed melting point with (A) material was 304–305° dec. The ultraviolet spectrum, evidently the same as the curve already published,[12] had maxima at 231, 247, 292, 351, 369, and 402 mμ (log ϵ 4.56, 4.51, 4.31, 3.39, 3.45, and 3.47, respectively), with shoulders at 255, 301, and 334, and minima at 240, 271, 327, 358, and 378 mμ.

(C) A sample of "IND-745" received from Dr. F. C. Uhle was found to have a m.p. of 297–298° dec. The mixed melting point with material, m.p. 301–302° dec., from (A) was 298–299° dec. The infrared and ultraviolet spectra were identical.

(D) A suspension of 1.0 g. of 2-carbomethoxy-3-chloro-7-aminobenzo[*f*]quinoline-6-carboxylic acid lactam in 100 ml. of methanol was treated with sodium borohydride in small portions. Exothermic, effervescent reaction took place, converting the original crystals into dense, bright yellow, granular material. The material was warmed on a steam bath for 15 min., after addition of a little more sodium borohydride. The cooled suspension was diluted with water and the solid XXXVI was collected, washed with water, and air dried. The product, 0.9 g. of bright yellow powder, m.p. 257–259° dec., could not be recrystallized properly; the infrared spectrum was poorly resolved, showing a broad band in the OH/NH region and peaks at 5.89 (shoulder at 5.80) and 6.09 μ.

Anal. Found: C, 63.65; H, 4.02; N, 9.55.

The sodium borohydride reduction product (0.5 g.) and 1 g. of 10% palladium-charcoal were suspended in 280 ml. of xylene, and the mixture was refluxed vigorously for 1.5 hr. The filtered solution deposited *ca.* 0.1 g. of bright golden yellow needles upon cooling; when recrystallized from methanol these had a m.p. of 300–301° dec., and the infrared spectrum was identical with that of preceding samples, (A) and (B).

7-Aminobenzo[f]quinoline-2,6-dicarboxylic acid lactam (XXXV. R = H). Hydrolysis of 0.3 g. of ester from the preceding experiment with 100 ml. of concd. hydrochloric acid (refluxed 0.5 hr.) gave orange crystals, m.p. >360°, after recrystallization from methanol.

The infrared spectrum had strong bands at 3.03 and 5.80–5.83 μ, as well as intense, sharp peaks at 755 and 789 cm.$^{-1}$; there were also very broad, weak bands at 3.84–4.35 μ. Analysis showed that there had not been decarboxylation during the hydrolysis; the compound was soluble in alkali.

Anal. Calcd. for $C_{15}H_8O_3N_2$: C, 68.18; H, 3.05; N, 10.60. Found: 68.0; H, 3.18; N, 10.66.

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