ULTRAVIOLET SPECTRA OF ALKALOIDS

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I. INTRODUCTION AND SCOPE

The use of ultraviolet spectra in structural elucidation is a time-honored method, and particularly applicable to many problems involving natural products. Although there are many very useful collections of ultraviolet spectral data which include some alkaloids (187, 188, 205, 328), and also collections of a limited number of alkaloids (250, 255), there have been no serious attempts to bring together these data for this class of compounds as a whole.

In examining the ultraviolet spectra of the alkaloids, a number of basic facts should be borne in mind. First, there are a large number of alkaloids of varying structural types; for example, most of the pyrrolidine and diterpene alkaloids, which have no ultraviolet spectra in the commonly recognized sense (see below) and so are not included in this review. Some structural types are, however, included because of chromophore-containing substituents; for example, the pyrrolizidine and tropane alkaloids.

Secondly, it should be recognized that the ultraviolet spectral method is only one of a large and growing number of physical methods for the determination of molecular structure, and wherever possible these methods should be used in the particular structural investigation (295, 337). The plant source may also be of great value in giving leads to possible structural types (344).

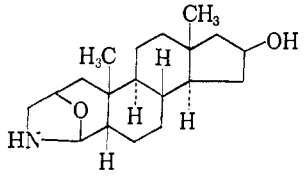
It is not within the scope of this review to include data on alkaloids of unknown structure, and this omission includes cases where opinions as to the type of structure have been propounded on the basis of the plant origin and the ultraviolet spectra. This review has also not considered quantitative applications of ultraviolet spectra, such as the determination of molecular weight or its use in pK determinations.

There are some instances where data have been included on alkaloid degradation products, since the ultraviolet spectra of these compounds played significant roles in structural elucidation. Nonalkaloidal models are sometimes included to illustrate some particular chromophoric feature.

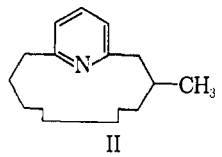
A. CLASSIFICATION

The definition of an alkaloid being a basic nitrogenous compound occurring in plants and usually having some physiological activity (276) seems to have been

discarded. Several alkaloids have been isolated from animals; for example, samandarine (I) from *Salamanda maculosa*, muscopyridine (II) from the musk deer, castoramine (III) from the Canadian beaver, and pyocyanine (IV) extracted from the bacteria *Pseudomonas aeruginosa*.



I



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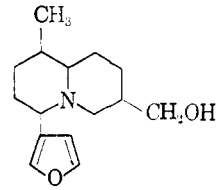

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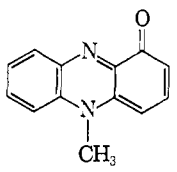
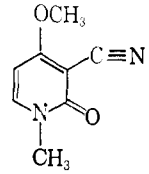
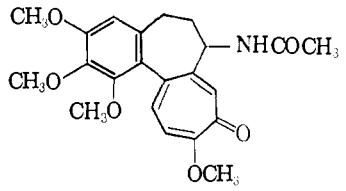


IV



V



VI

Some alkaloids are also nonbasic. The neutral alkaloids ricinine (V) and colchicine (VI) exemplify this exception. Some groups of compounds have also been classified as alkaloids by some authors and not as alkaloids by others. The purine bases (*e.g.*, caffeine) fall into this category. They have been included in classifications by Boit (56), Kirk and Othmer (213), but omitted by Henry (185) and Manske and Holmes (231). We have included these bases as genuine alkaloids. In this review the alkaloids have been grouped together in conventional structural lines. The presentation of these groups is from the simple to the more complex. Note should be taken of the fact that certain groups of alkaloids are discussed with others of similar chromophoric pattern. For example, the Lycopodium alkaloids are discussed with the pyridine–pyridone group, and certain sesquiterpene alkaloids included with the quinolizidines because of similar structural features. All the dihydroindole and indole alkaloids are subdivided with respect to their chromophores rather than the classification used by Boit, and so the indolylalkylamine, physostigmine, calycanthine, canthine, yohimbine, corynanthine (alstonine, oxindole, strychnine, ibogaine, aspidospermine, eburnamine, ellipticine, mavacurine), fluorocurine, cryptolepine, some members of the cinchonamine group, and ergot alkaloids are to be found in this section.

The Amaryllidaceae alkaloids, although having several structural types, have been kept together for easy reference.

The isobutylamides have not been included in the review.

The miscellaneous group contains alkaloids which, because of their novel structures, are dissimilar to the recognized types.

B. DEFINITION OF TERMS

The review by Dorfman (114) of the ultraviolet spectra of steroids contains an excellent summary of spectroscopic terms. For convenience these are repeated here with modifications and expansion to comply with currently accepted nomenclature (312).

ULTRAVIOLET.—This usually refers to the region of the electromagnetic spectrum from 200 to 380 mμ.

VISIBLE.—The spectral range visible to the human eye, that is, *ca.* 380 to 780 mμ.

CHROMOPHORE.—A structural feature which results in ultraviolet light absorption or color in the visible.

ABSORBANCE, A.—Logarithm to the base 10 of the reciprocal of the transmittance: $A = \log (1/T)$ where T = transmittance.

ABSORPTIVITY, a.—$a = A/bc$ where b is the sample path length in cm., and c is the concentration of the substance in g./l.

ABSORPTIVITY, Molar, ϵ.—The product of the absorptivity and the molecular weight of the substance which replaces the former terms, molar absorbancy index, molar absorption coefficient, and molar extinction coefficient.

LOG ABSORPTIVITY, Molar, ϵ.—Log ϵ.

WAVE LENGTH UNITS, λ.—Millimicrons, 1 mμ = 10^{-7} cm.

AUXOCHROME.—A group which enhances the absorptivity of a chromophore.

BATHOCHROMIC SHIFT.—The shifting of an absorption band toward longer wave lengths.

HYPSOCHROMIC SHIFT.—The shifting of an absorption band towards shorter wave lengths.

HYPERCHROMIC SHIFT.—An increase in the ϵ-value of an absorption band.

HYPOCHROMIC SHIFT.—A decrease in the ϵ-value of an absorption band.

The measurement of ultraviolet spectra until recently has been subject to instrumental limitation, so in this review an ultraviolet spectrum constitutes the measurement of absorptivity in the region from *ca.*

205 mμ into the visible. This range excludes most alkaloids that contain only an isolated double bond.

It should be remembered that an ultraviolet spectrum is characteristic of a certain chromophoric system or systems, rather than the molecule as a whole, and that structural changes involving the chromophore can make significant changes in the ultraviolet spectrum.

C. SPECTRAL PRESENTATION

There are many different ways of presenting ultraviolet spectra (141, 290), the most common being the plot of ϵ or log ϵ against wave length , λ (mμ). In the present review log ϵ values are plotted or tabulated against λ (mμ). In the tables, the alkaloids are arranged alphabetically with λ_{max} and log ϵ values; also λ_{min} and log ϵ values are given for some compounds including those compounds whose spectra have been shown. In a few examples, ϵ-values are plotted to illustrate particular solvent effects. The log ϵ plot has the advantage of compressing the high ϵ-values and enhancing the weaker values, thus avoiding the necessity in some cases for changes of scale. The following additional points should be noted.

(a) All the curves (log ϵ, λ) are plotted on the same scale.

(b) In many cases, the data used for tables or graphs were obtained from other graphs.

(c) The review attempts to be as exhaustive as possible of the different chromophoric types within a given group of alkaloids and includes data published up to April 1964. In much of the early classical work on alkaloids, no ultraviolet spectra are recorded. In several cases, however, authors have kindly sent us data from their own unpublished collections. We wish to acknowledge particularly the large number of spectra of indole and dihydroindole alkaloids from the Lilly collection (249).

(d) There are a few groups for which no graphs are given because of their simple chromophore pattern or because inadequate data prevented the plotting of a graph. The quinolizidine, imidazole, and pyrrolizidine groups are examples of the former case.

D. SOLVENT

Most of the spectra of the alkaloids or alkaloid salts have been determined in polar hydroxylic solvents (ethanol, methanol, or water). For this reason there is rarely any significant fine structure shown. The main interest has been in the effect of pH changes on the spectra. In many cases, variations in pH cause significant structural changes in the molecule which are reflected in changes of the ultraviolet spectra.

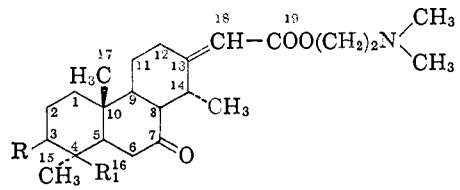
In a number of cases spectral differences due to solvent effects have also been discussed.

II. SIMPLE AMINE DERIVATIVES

There are a number of structural types which can be classified as aliphatic amines or phenylalkylamines. The ultraviolet spectra are generally due to either an α,β-unsaturated carbonyl function or an aromatic ring. In some cases the aromatic ring is conjugated with the side chain.

A. α,β-UNSATURATED CARBONYL AMINES

Some examples of this type are the *Erythrophleum* alkaloids (VII) which are amino alcohol esters of unsaturated diterpene acids.



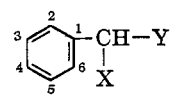
VII

a	Cassaine	R = H,	R_1 = CH_3
b	Cassamine	R = H,	R_1 = $COOCH_3$
c	Erythrophlyamine	R = OH,	R_1 = $COOCH_3$

The alkaloids (123, 289) and the free acids show (152) absorption maxima at ~220–225 mμ (log ϵ 4.2) due to the unsaturated ester or acid.

B. PHENYLALKYLAMINES

The aromatic ring may be either unconjugated as in VIII or conjugated with carbonyl or olefinic functions as in leonurine (IX), sinapine (X), and aegeline (XI). The unconjugated types show a simple absorption envelope at ~260–280 mμ, the position and intensity depending on the auxochromic substituents (OH, OCH_3) on the aromatic ring. In the conjugated types, the absorption band is bathochromically shifted and increased in intensity. Examples of these types are summarized in Table I.



VIII

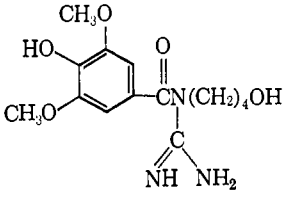
		3	4	5	X	Y
a	Capsaicin	OCH_3	OH	...	H	$NHCO(CH_2)_4CH{=}CHCH(CH_3)_2$
b	Ephedrine and pseudoephedrine	...	...	...	OH	$CH(CH_3)NHCH_3$
c	Mescaline	OCH_3	OCH_3	OCH_3	H	CH_2NH_2
d	N-Methylephedrine	...	...	...	OH	$CH(CH_3)N(CH_3)_2$
e	Norpseudoephedrine	...	...	...	OH	$CH(CH_3)NH_2$

TABLE I

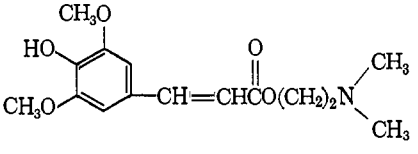
SIMPLE AMINE DERIVATIVES

Compound	$\lambda_{max.}$ mμ	Log ε	$\lambda_{min.}$ mμ	Log ε	Solvent	Ref.
α,β-Unsaturated carbonylamines						
Cassaine	223	4.26	...	...	E	289
Cassamine	225	4.2	...	...	E	123
Erythrophlyamine	222	4.2	...	...	E	123
Phenylalkylamines						
Capsaicin	227, 281	3.85, 3.40	...	...	E	100
Ephedrine	253, 259, 264	2.27, 2.31, 2.26	241, 254, 261	1.82, 2.20, 2.20	I	122
Ephedrine hydrochloride	251, 257, 264	2.18, 2.25, 2.18	235, 253, 261	1.26, 2.16, 2.16	W	122
Mescaline	225 sh, 269	4.2, 3.2	253	2.81	E	4, 255, 293
N-Methylephedrine hydrochloride	251, 257, 264	2.20, 2.27, 2.19	235, 253, 260	1.56, 2.16, 2.16	W	122
Norpseudoephedrine hydrochloride	251, 257, 264	2.11, 2.11, 2.20	235, 253, 260	1.48, 2.06, 2.06	W	122
Conjugated phenylalkylamines						
Aegeline	217, 223, 275	4.53, 4.52, 4.61	...	...	E	85
Leonurine	276	4.0	...	...	M	162
	239, 326	4.3, 4.7	...	...	OH^-	
Sinapine iodide	223, 240 sh, 333	4.3, 4.13, 4.27	270	3.13	E	219

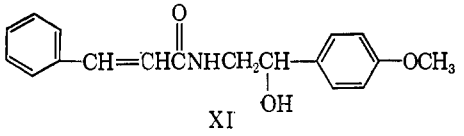
[a] In this and in other tables the following abbreviations have been used for solvents: B = buffered solution and pH stated when available; Ch = chloroform; Cy = cyclohexane; D = dioxane; E = ethanol (95%-absolute); E% = ethanol of stated lower per cent; Eth = ether; H^+ = acid solution (with normality (*N*) if given); H = hexane; I = isopropyl alcohol; M = methanol; OH^- = alkaline solution (with normality (*N*) if given); W = water.



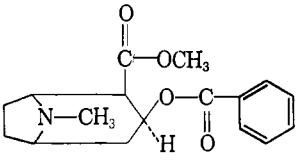
IX



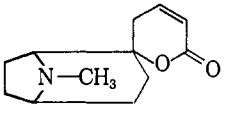
X



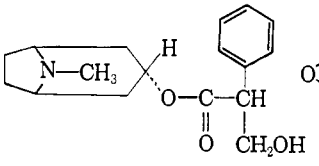
XI



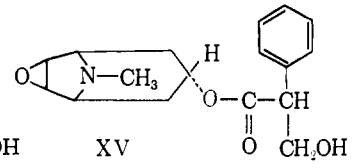
XII



XIII



XIV



XV

The sulfate of atropine (XIV), hyoscyamine (XIV), and the hydrobromide of *l*-scopolamine (XV) have similar ultraviolet spectra owing to the aromatic ring. These values are summarized in Table II.

III. TROPANE GROUP

Some members of this group of alkaloids have an ultraviolet spectrum simply because of chromophore-containing substituents. Cocaine (XII) (Figure 1) shows an ultraviolet spectrum with maxima at 230, 274, and 281 mμ (log ε 4.19, 2.98, and 2.89) owing to the O-benzoyl substituent. The hydrochloride shows a merging of two maxima to give a spectrum with bands at 253 and 274 mμ (log ε 4.09 and 3.02). Dioscorine (XIII) shows a maximum at 217 mμ (log ε 4.20) owing to the unsaturated δ-lactone substituent on the tropane ring.

IV. STEROIDAL ALKALOIDS

Solanidine, like many steroidal aglycones, contains only one isolated double bond and so displays only a weak general absorption in the ultraviolet (91), which is outside the range of most instruments. Cevadine, the natural occurring ester of cevine (XVI) (Figure 1) shows a band at 296 mμ (log ε 1.84) (25, 259). The fine structure which is normal for the benzene moiety is absent in the spectrum of veratramine (XVII) (Figure 1). Jervine (XVIII) (Figure 1), with bands at 250 (log ε 4.2) and 360 mμ (log ε 1.88) (199) shows a spectrum which is typical of a trisubstituted α,β-un-

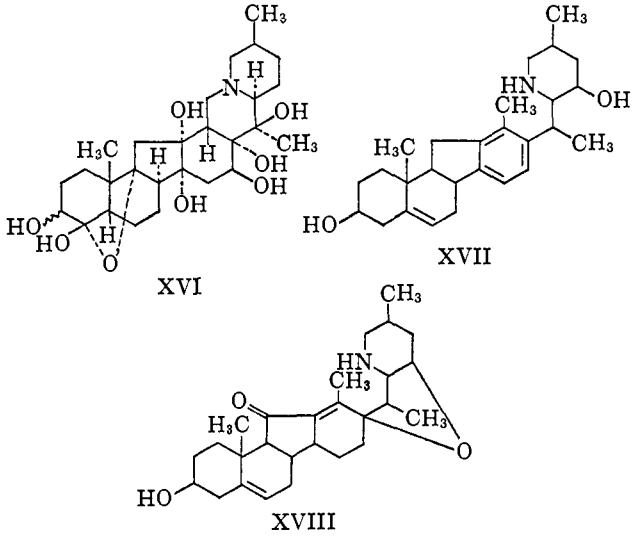
TABLE II

TROPANE GROUP

Compound	$\lambda_{max.}$ mμ	Log ε	$\lambda_{min.}$ mμ	Log ε	Solvent[a]	Ref.
Atropine sulfate	247, 252, 255, 264	2.22, 2.27, 2.30, 2.27	245, 250, 254, 261	2.12, 2.12, 2.13, 2.12	E	122
Cocaine	230, 274, 281	4.19, 2.98, 2.89	216, 261, 279	3.92, 2.85, 2.88	W	255
Cocaine hydrochloride	233, 274	4.09, 3.02	211, 261	3.62, 2.89	W	255
Dioscorine	217	4.20	...	...	?	263
Hyoscyamine sulfate	247, 252, 255, 264	2.22, 2.27, 2.30, 2.27	245, 250, 254, 261	2.12, 2.12, 2.13, 2.12	E	122
l-Scopolamine hydrobromide (hyoscine)	249, 252, 259, 263	2.02, 2.08, 2.14, 2.06	245, 250, 256, 261	1.9, 1.9, 1.9, 1.9	E	122

[a] E = ethanol (95%–absolute); W = water.

saturated ketone (348, 349). See Table III for a summary of data of this group.



XVI XVII XVIII

V. PYRROLIZIDINES

Complete structural elucidation of many pyrrolizidine alkaloids has been greatly aided by alkali hydrolysis to yield the "necine" (alkanolamine) fragment and "necic" acid or acids depending on whether the alkaloid contains a monoester with a monocarboxylic acid, a diester of necine with different monocarboxylic acids, or a cyclic diester with a dicarboxylic acid. Ultraviolet spectroscopy has been most useful in the identification of the necic acids and, where applicable, also gives information about the intact alkaloid structure.

TABLE III

STEROIDAL ALKALOIDS

Compound	$\lambda_{max.}$ mμ	Log ε	Solvent[a]	Ref.
Cevadine	296 (λ_{min} 280)	1.84 (1.76)	E	259
α-Cevine	280	0.5	E	319
γ-Cevine	252	1.4	E	319
δ-Cevine	250, 305	1.5, 1.28	E	319
β-Germine	*Ca.* 280	2.2	E	266
Isogermine	*Ca.* 250	2.0	E	266
Jervine	250, 360 (λ_{min} 306)	4.2, 1.88 (1.4)	E	139
Veratramine	268 (λ_{min} 245)	2.8 (2.3)	E	198

[a] E = ethanol (95%–absolute).

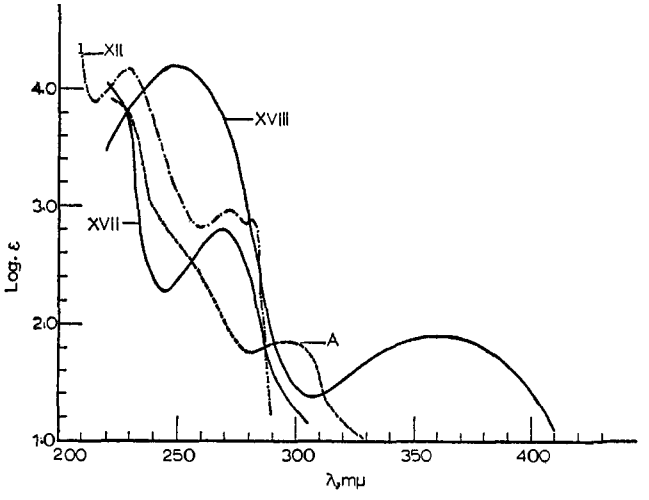
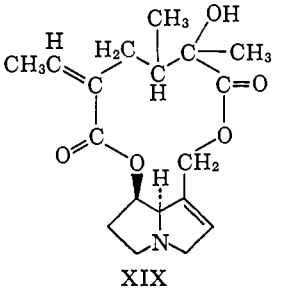
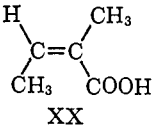


Figure 1.—Tropane and steroidal groups. Tropanes: cocaine (XII) in water. Steroidal group: (A) cevadine, the ester of cevine (XVI), in ethanol; veratramine (XVII) in ethanol; jervine (XVIII) in ethanol.

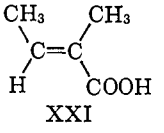
The isolated double bond which is present in the pyrrolizidine ring of many senecio alkaloids, for example, usaramoensine (XIX), absorbs below 200 mμ, and so the ultraviolet spectra of these alkaloids above 200 mμ (Table IV) depend upon the nature of the acid attached.



XIX



XX



XXI

The ultraviolet spectra of the necic acids (Table V) may be useful in assigning geometrical configuration of the acid. The configuration of angelic acid (XX) was shown to be *cis* by comparing it with tiglic acid (XXI)

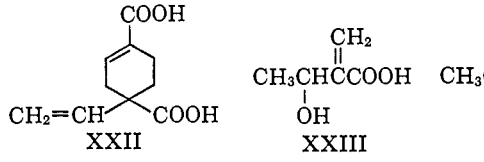
TABLE IV

PYRROLIZIDINES

Compound	λ_{max}, mμ	Log ε	Solvent[a]	Ref.
Integerrimine	212	4.03	E	224
Jacozine	233	3.24	E	103
Retrorsine	217.5	3.85	E	223
Rosmarinine	218	3.78	W	223
Senecionine	215	3.32	E	3
Spartioidine	215	4.00	E	224
Usaramoensine	203	4.10	E	3

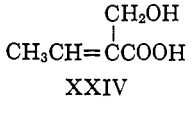
[a] E = ethanol (95%-absolute); W = water.

(*trans*) (3). The absorptivity for tiglic acid (ε 13,500, 212 mμ) is much higher than that of angelic acid (ε 9500, 216 mμ). It is, however, important to bear in mind that alkaline hydrolysis may cause a change in the geometrical configuration about an α,β carbon–carbon double bond in the acid fragments (224), and also that some acids isolated result from the rearrangement of primary products. Mikanecic acid (XXII), for example, is formed by the action of alkali on sarracenic acid (XXIII or XXIV) (104). Jacozine (XXV) with λ_{max} 233 mμ (log ε 3.24) has recently been shown to be the epoxide of seneciphylline.



XXII

XXIII



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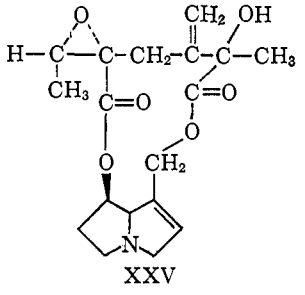
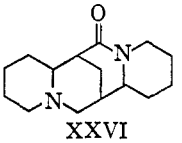


XXV

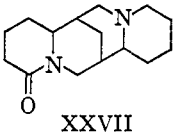
VI. QUINOLIZIDINES

Consideration of the ultraviolet spectra of this group can be confined mainly to (a) the carbonyl-containing lupin alkaloids subdivided into (i) a carbonyl group adjacent to a tertiary nitrogen, (ii) the grouping O=C=C=C—N—, (iii) a C=C—N—C=O grouping, and (iv) a substituted 2-pyridone type system; and (b) no carbonyl groups (Table VI).

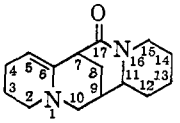
Oxysparteine (XXVI) and lupanine (XXVII) show a single maximum at ~214 mμ (log ε 3.8). It should be noted that the introduction of a single isolated double bond as exemplified by 5,6-dehydro-17-oxosparteine (XXVIII) and 2,3-dehydro-17-oxosparteine (XXIX) markedly alters the ultraviolet spectrum. Effects of this kind are usually due to some type of nonconjugated electronic interactions.



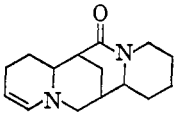
XXVI



XXVII



XXVIII



XXIX

Multiflorine (XXX) with a O=C—C=C—N— grouping shows a maximum at 326 mμ and shows a hypsochromic shift of 6 mμ in 0.02 *N* hydrochloric acid.

Aphyllidine (XXXI, R = OH) and argyrolobine (XXXI, R = H) both have spectra characteristic of the C=C—N—C=O grouping with a maximum at ~240 mμ.

The fourth group contains cytisine (XXXII, R = H), methylcytisine (XXXII, R = CH_3), anagyrin (XXXIII, R = H), and baptifoline (XXXIII, R =

TABLE V

NECIC ACIDS

Compound	Parent alkaloid	λ_{max}, mμ	Log ε	Solvent[a]	Ref.
Angelic acid (*cis*)	Echmidine, echiumine, heliosupine, lasiocarpine, lindelofamine, macrophylline, sarracine, turneforcine	216	3.97	E	3
Integerrinecic acid (*trans*)	Integerrimine	214	3.95	E	3
Integerrinecic acid lactone	Integerrimine	222	4.08	E	3
Isatineic acid	Retrosine	214	3.92	E	4
Jacozinecic acid	Jacozine	211	3.05	E	103
Mikanecic acid	Sarracine	216	4.06	E	104
Platynecic acid	Platyphylline	219	3.80	?	223
Riddelic acid	Riddelliine	215	3.91	E	4
Senecic acid (*cis*)	Rosmarinine Senecionine	215	3.79	E	3
Seneciphyllic acid	Seneciphylline	214	3.91	E	224
[Tiglic acid]—model compound (*trans*)		212	4.13	E	3
Usaramoensinecic acid (*cis*)	Usaramoensine	215	3.77	E	3

[a] E = ethanol (95%-absolute).

TABLE VI

QUINOLIZIDINES

	Compound	λ_{max}, mμ	Log ε	Solvent[a]	Ref.
(a)					
(i)	Lupanine perchlorate	215	3.7	E	120
	Oxysparteine	212	4.0	Eth	54
	5,6-Dehydro-17-oxosparteine	212, 247	4.0, 3.7	Eth	54
	2,3-Dehydro-17-oxosparteine	242	4.2	Eth	54
(ii)	Multiflorine	326	4.16	E	95
		320	4.14	H^+ (0.02 *N*)	95
		300	4.14	Cy	95
(iii)	(+)-Aphyllidine	248	4.1	?	101
	(−)-Aphyllidine	240	4.07	E	326
	Argyrolobine	239	3.97	E	326
(iv)	Anagyrine perchlorate	233, 309	3.82, 3.89	M	55
	Baptifoline	233, 309	3.84, 3.91	M	55
	Cytisine	235, 308 (λ_{min} 253)	3.7, 3.8 (2.8)	M	294
	Methyl cytisine	234, 309	3.80, 3.90	M	55
(b)	α-Isosparteine	216	3.79	Eth	225
	Sparteine	214	3.71	Eth	225

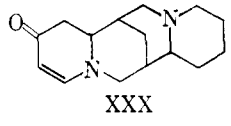
[a] See footnote in Table I for key to solvents.

TABLE VII

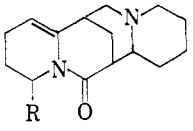
IMIDAZOLES

Compound	λ_{max}, mμ	Log ε	λ_{min}, mμ	Log ε	Solvent[a]	Ref.
Imidazole	211	3.70	...	...	E	61
Casimiroedine	218, 280	4.26, 4.33	244	2.0	E	5, 111, 211
Tetrahydrocasimiroedine	280	3.38	240	2.85	E	5

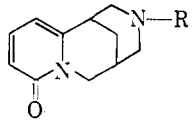
[a] E = ethanol (95%–absolute).



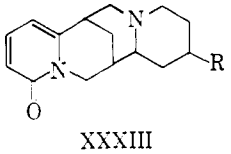
XXX



XXXI



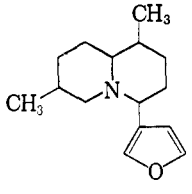
XXXII



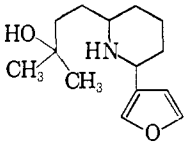
XXXIII

OH). All these alkaloids show spectra with two maxima, one at *ca.* 234 mμ and the other at 308–309 mμ. Spectra of these lupins and those of 2-pyridone alkaloids (*e.g.*, β-obscurine) may be distinguished by the fact that for the former compounds, the band at lowest wave length has a lower ε-value than the second maximum, while in the latter compounds, the reverse is the case.

Certain sesquiterpene alkaloids, for example, desoxynupharidine (XXXIV) and nupharamine (XXXV), can be regarded as being derivatives of the quinolizidine ring and so might be included here.

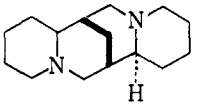


XXXIV



XXXV

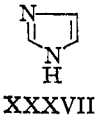
The spectra of these compounds depend on the presence of a furan ring which shows a maximum at *ca.* 200 mμ (log ε 4.0). A point of some interest is that sparteine (XXXVI) and its *cis–cis* isomer α-isosparteine both show a maximum above 200 mμ. In ether, sparteine has a maximum at 214 mμ (log ε 3.71) and α-isosparteine shows a band at 216 mμ (log ε 3.79) (225).



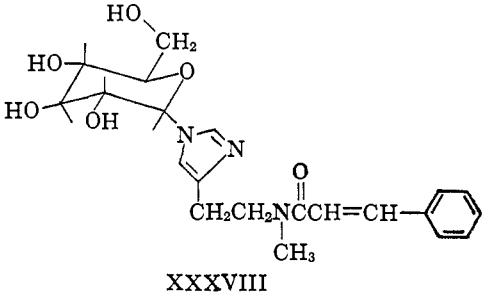
XXXVI

VII. IMIDAZOLES

The imidazoles (1,3-diazoles or glyoxalines) are a small group of alkaloids with no appreciable ultraviolet absorption above 220 mμ (108). The spectrum of imidazole (XXXVII) shows a maximum at 211 mμ (log ε 3.70) and a weak maximum at 250 mμ (log ε 1.78) (61, 314).



XXXVII



XXXVIII

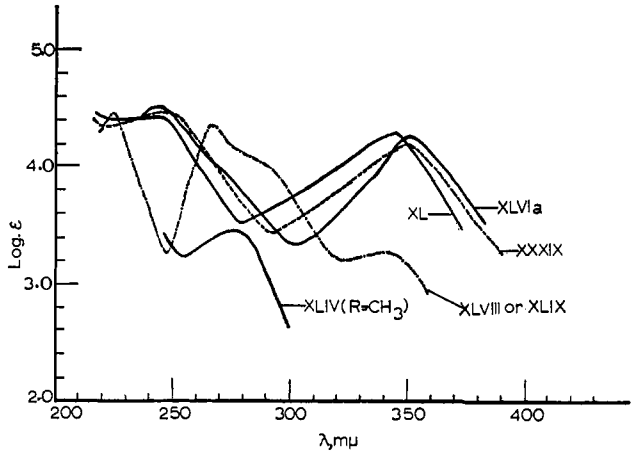
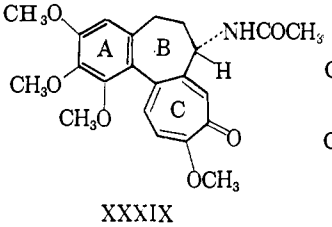


Figure 2.—Tropolone group: colchicine (XXXIX) in ethanol; isocholchicine (XL) in ethanol, colchiceine (XLVIa) in ethanol; allocolchicine (XLIV, R = CH_3) in ethanol; β- or γ-lumicolchicine (XLVIII and XLIX) in ethanol.

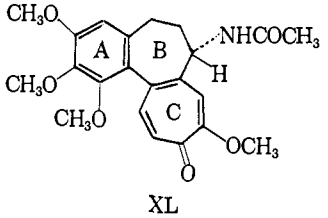
The maxima shown by casimiroedine (XXXVIII) (a derivative of N-cinnamoyl-N-methylhistamine) (272) at 219 and 280 mμ are essentially due to the extended aromatic chromophore. These values are summarized in Table VII.

VIII. Tropolone Group

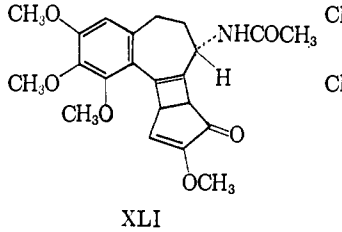
The tropolone group of alkaloids can be classified into two main types: the colchicine (XXXIX)–isocolchicine (XL) group and the lumicolchicines (XLI, XLII). The ultraviolet spectra are significantly different. The lumicolchicines originally produced from colchicine have also been found naturally occurring. Although the lumicolchicines do not contain the tropolone ring system they are conveniently considered with this group.



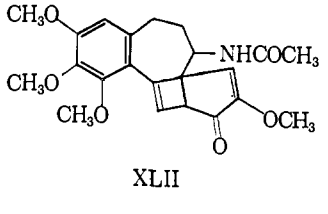
XXXIX



XL



XLI



XLII

A. Colchicine Group

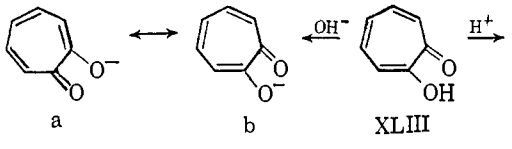
Simple tropolones are characterized by two main regions of absorption showing marked fine structure in nonpolar solvents (253): (a) an intense absorption in the region 200–300 mμ (ϵ 10,000–100,000); (b) a weaker absorption in the region 300–400 mμ (ϵ 1000–10,000). The latter band shows two maxima of about equal intensity at 300–350 and 350–400 mμ.

In the case of tropolone (XLIII), the bands (in aqueous solution) occur at 228 (log ϵ 4.36), 237 (4.36), 320 (3.83), and 351 mμ (3.76). There is more fine structure shown in cyclohexane solution (253).

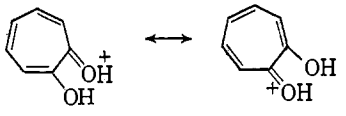
The long wave length bands show a bathochromic shift in both acid and alkaline solution attributed (113, 258) to the formation of various resonance forms (XLIIIa–d).

The tropolone alkaloids possess an aromatic ring in conjugation with the tropolone ring and the ring-C hydroxyl is usually methylated (except in the colchiceine series).

Colchicine (XXXIX), the parent tropolone alkaloid, has maxima at 247 (log ϵ 4.45) and 355 mμ (4.20). The



a b XLIII

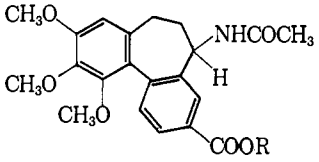


c d

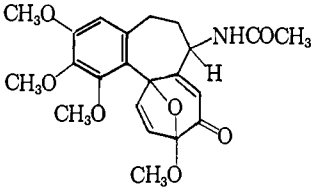
long wave length band appears as a broad maximum. The spectrum of isocolchicine (XL) is similar to that of colchicine with the long wave maximum appearing at somewhat lower wave length, 345 mμ (log ϵ 4.28) (Figure 2). The difference is due to the differing bond structures in the two isomers.

The conjugative effect between rings A and C has been discussed with reference to the mutarotation of isocolchicine (275).

Colchicine and other colchicine alkaloids show a facile rearrangement in the presence of methanolic sodium methoxide to the allo series (XLIV). In these compounds the tropolone ring system is no longer present, and the spectrum only shows a maximum at 278 mμ (296), typical of a substituted biphenyl: (a) XLIV (R = H), allocolchiceine; (b) XLIV (R = CH_3), allocolchicine (*cf.* Figure 2).



XLIV



XLV

TABLE VIII

TROPOLONE GROUP

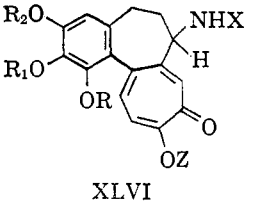
Compound	$\lambda_{max.}$ mμ	Log ε	$\lambda_{min.}$ mμ	Log ε	Solvent[a]	Ref.
		Colchicines				
Tropolone	228, 237, 320, 351	4.36, 4.36, 3.83, 3.76	...	...	W	253
Allocolchiceine	278	5.14	254	4.94	OH^- (0.05 *N*)	296
Colchiceine	244, 351	4.51, 4.28	...	...	E	193
Colchiceine	243, 267 sh, 350, 394sh	4.51, 4.03, 4.26, 4.20	302	3.35	M, OH^- (0.05 *N*)	253, 296
Colchiceine ethyl ether	233 sh, 244, 351	4.44, 4.45, 4.21	...	...	E	193
Colchicine	234 sh, 246, 355	4.46, 4.49, 4.22	220, 292	4.36, 3.46	E	125, 131, 297, 303
Cornigerine[b]	238, 353	4.5, 4.23	292	3.75	E	176
Demecolceine ethyl ether	245, 350	4.55, 4.3	220, 290	4.43, 3.72	E	327
Demecolcine	245, 355	4.55, 4.24	215, 290	4.35, 3.7	E	327
Desacetylisocolchicine	244, 345	4.49, 4.28	223, 279	4.37, 3.6	E	327
2-Desmethylcolchicine	245, 353	4.54, 4.27	220, 292	4.42, 3.65	E	297
3-Desmethylcolchicine	240, 353	4.55, 4.26	220, 293	4.49, 3.66	E	297
N-Formyldesacetylcolchicine	247, 350	4.51, 4.27	220, 292	4.42, 3.60	E	297
Isocolchiceine ethyl ether	229, 247, 343	4.41, 4.53, 4.30	233, 283	4.44, 3.72	E	193, 297
Isocolchicine	244, 345	4.44, 4.28	226, 278	4.40, 3.60	E	193, 297
Isodemecolceine ethyl ether	247, 345	4.48, 4.28	234, 296	4.32, 3.54	E	327
Isodemecolcine	245, 345	4.54, 4.25	222, 279	4.38, 3.6	E	327
Oxycholchicine	234, 281	3.24, 2.5	...	...	E	72
		Lumicolchicines				
β-Lumicolchicine	225, 266, 282 sh, 340	4.46, 4.36, 4.10, 3.29	248, 322	3.26, 3.23	E	170, 297
γ-Lumicolchicine	Spectrum identical with β-isomer				E	170, 297
Lumiisocolchicine	218, 260	4.42, 4.34	...	...	E	83

[a] See footnote in Table I for key to solvents. [b] Structure not completely established.

The oxidation of colchicine to oxycolchicine (XLV) with acidified potassium dichromate also results in a loss of the tropolone ring absorption at 350 mμ (72).

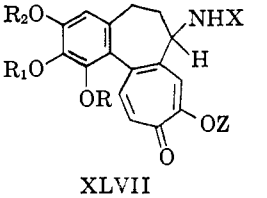
The spectra of the demecolcine (XLVId) and isodemecolcine (XLVIIe) are similar to colchicine and isocolchicine, respectively.

Spectral data for the number of colchicines (XLVIa–g) and isocolchicines (XLVIIa–f) are summarized in Table VIII.



XLVI

	R	R_1	R_2	X	Z
a Colchiceine	CH_3	CH_3	CH_3	$COCH_3$	H
b Colchicine	CH_3	CH_3	CH_3	$COCH_3$	CH_3
c Demecolceine ethyl ether	CH_3	CH_3	CH_3	CH_3	C_2H_5
d Demecolcine (colchamine)	CH_3	CH_3	CH_3	CH_3	CH_3
e 2-Desmethylcolchicine	CH_3	H	CH_3	$COCH_3$	CH_3
f 3-Desmethylcolchicine	CH_3	CH_3	H	$COCH_3$	CH_3
g N-Formyldesacetylcolchicine	CH_3	CH_3	CH_3	CHO	CH_3



XLVII

	R	R_1	R_2	X	Z
a Desacetylisocolchicine	CH_3	CH_3	CH_3	H	CH_3
b Isocolchiceine	CH_3	CH_3	CH_3	$COCH_3$	H
c Isocolchicine	CH_3	CH_3	CH_3	$COCH_3$	CH_3
d Isocolchicine ethyl ether	CH_3	CH_3	CH_3	$COCH_3$	C_2H_5
e Isodemecolcine	CH_3	CH_3	CH_3	CH_3	CH_3
f Isodemecolcine ethyl ether	CH_3	CH_3	CH_3	CH_3	C_2H_5

B. LUMICOLCHICINES

These compounds occur naturally and are also produced by irradiation of colchicine with ultraviolet light. The valence tautomeric rearrangement reaction (254) gives rise to two stereoisomers containing a cyclobutane ring C (XLVIII). The two isomers known as β- and γ-lumicolchicines show absorption maxima at 225, 266, 280 (sh), and 340 mμ. The shift of the maxima to shorter wave length compared with colchicine was one

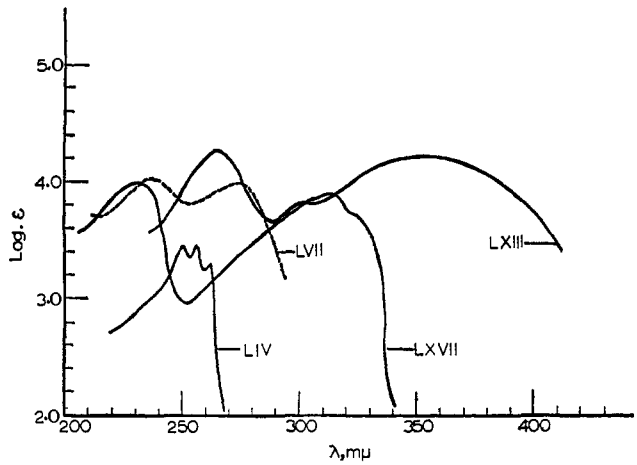
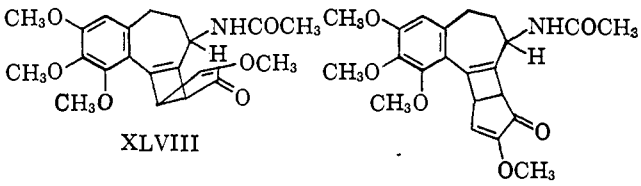


Figure 3.—Pyridine group: pyridine (LIV) in ethanol; 2,3′-dipyridine (LVII) in ethanol; N-methylhalfordinium chloride (LXIII) in ethanol; β-obscurine (LXVII) in ethanol.

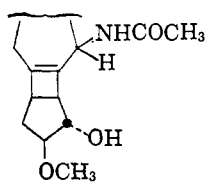
of the early indications that the extended conjugation of the colchicine molecule had been interrupted (135).



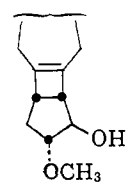
XLVIII

XLIX

The two isomers, β- and γ-lumicolchicine, have been assigned structures XLVIII and XLIX, respectively, and these structures have been confirmed by a study of the spectra of the tetrahydro derivatives. Weak intermolecular hydrogen bonding shows up with a decrease in ε-values as the concentration is decreased in a nonpolar solvent even though the chromophore responsible for the maximum is not directly involved in the bonding. The change in ε-values for the two tetrahydro derivatives L (β) and LI (γ) have been studied, and the larger change is observed for the γ-isomer. This indicates that the β-isomer is significantly more intramolecularly hydrogen bonded (between the OH in ring D and the acetamido group in ring B) than the γ-isomer (147).

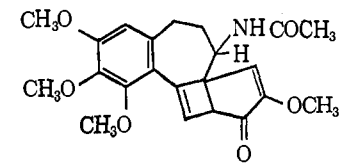


L

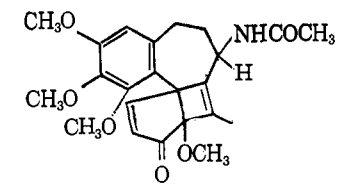


LI

The photoisomerization of isocolchicine (XL) has also been reported. Of the two possible structures for the photoisomers (LII and LIII), the former is favored on the basis of ultraviolet and spectral data (83). The presence of a trimethoxystyrl chromophore in LII rather than in LIII is deduced on the basis of the similarity of its ultraviolet spectrum with that of the β- and



LII



LIII

γ-lumicolchicines (83), though the band present at 340 mμ in the β- and γ-lumicolchicines has not been reported in the lumiisocolchicine spectrum. Spectral data for these compounds are summarized in Table VIII.

IX. Pyridine, Pyridone, and Piperidine Alkaloids Including Lycopodium Alkaloids

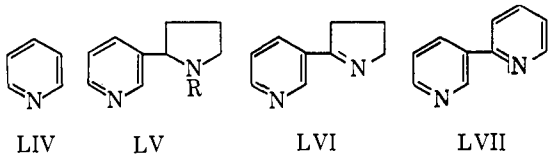
A. Pyridines

The ultraviolet spectrum of pyridine (LIV), λ_{max} 257 mμ (log ε 3.43) (Figure 3) in alcohol and hydrocarbon solvents shows a considerable degree of fine structure. This is lost in acid solution (324). The absorptivity of pyridine is increased in both acid and alkaline solutions (186). Spectral determinations of pyridine compounds are best done in 0.02 *N* ammonia so as to prevent the formation of pyridinium ions. The spectra of nicotine (LV, R = CH_3) and nornicotine (LV, R = H) are similar to pyridine but with a loss of fine structure and a bathochromic shift of 5 mμ to 262 mμ. Myosmine (LVI) with a dihydropyrrole conjugated with pyridine results in a further bathochromic shift (266 mμ) and the appearance of a new strong band at 234 mμ. The maxima of myosmine, nicotine, and nornicotine are little affected by dilute acid although the absorptivity is altered (324).

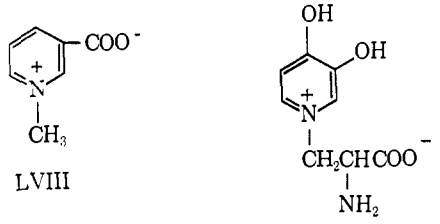
In 2,3′-dipyridine (isonicotine, LVII) (Figure 3), the above-mentioned shift is extended and this base has maxima at 237 and 275 mμ (log ε 4.06 and 4.00). According to Hakala and Schwert, the spectrum of trigonelline (LVIII) shows a dependence on hydrogen ion concentration which can be accounted for by the dissociation of the carboxyl group (175). No change was, however, noted in 0.5 *N* hydrochloric acid or in 0.05 *N* sodium hydroxide by other workers (194).

Mimosine (LIX) which has λ_{max} 282 mμ (log ε 4.23) in aqueous solution displays a hyposchromic shift at pH 2.2 to 276 mμ (log ε 3.97), and this shift in acid is common for hydroxypyridine derivatives (316).

Anibine (LX) with an α-pyrone ring conjugated with pyridine shows λ_{max} at 228.5 and 315 mμ and a shoulder

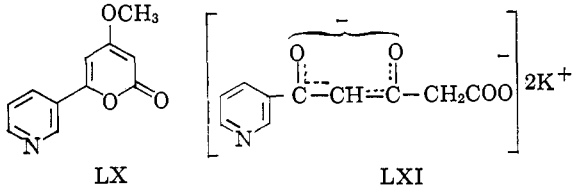


LIV LV LVI LVII

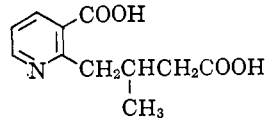


LVIII LIX

at 254 mμ. The spectrum is little affected in 1 *N* ethanolic hydrochloric acid, but in 1 *N* potassium hydroxide the solution turns yellow and the bands are immediately shifted to 253, 282, and 381 mμ (log ε 3.84, 3.72, and 4.16); after 1 week the spectrum of the now almost colorless solution shows a band at 334 mμ (log ε 3.36) (243). Analysis of this final product shows the loss of a methoxyl group, and the compound formed is formulated as LXI (243).

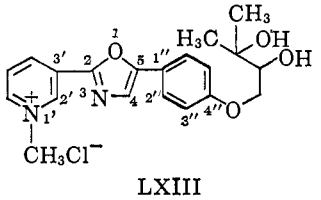


LX LXI

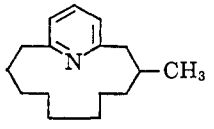


LXII

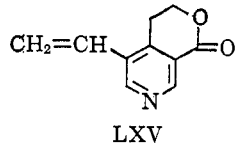
The ester alkaloid wilforine, which upon saponification yields the nitrogeneous dibasic acid LXII, is quite similar to myosmine (LVI) in spectral characteristics. N-Methylhalfordinium chloride (LXIII) [2,3′-pyridyl-5-(4′′-hydroxyphenyl)oxazole] shows a spectrum with two maxima, one being as high as 360 mμ (log ε 4.10) as a result of chromophoric extensions of the pyridine system by conjugation with oxazole and aromatic rings.



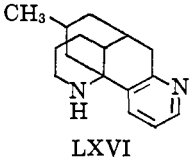
LXIII



LXIV



LXV



LXVI

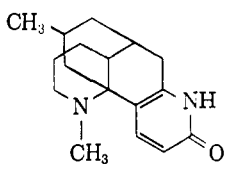
The large ring substituent as is found in muscopyridine (LXIV) results in a spectrum with two maxima at 213 and 267 mμ. Gentianine (LXV) with a lactone and a conjugated double bond has two maxima, at 220 and 280 mμ.

Lycodine (LXVI), a *Lycopodium* alkaloid (339), shows an ultraviolet spectrum characteristic of a substituted pyridine.

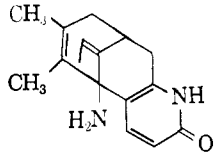
The elucidation of several alkaloid structures has been facilitated by degradation to pyridine products. The excellent review by Brody and Ruby lists degradative methods used and products obtained for several alkaloids (64). See Table IX for a summary of ultraviolet data on the pyridines.

B. PYRIDONES

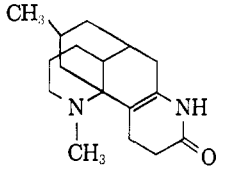
β-Obscurine (LXVII) (Figure 3) and selagine (LXVIII) which are *Lycopodium* alkaloids have ultraviolet spectra similar to model compounds, 2-pyridone (124) and 6-methyl-2-pyridone (242), except that the second maximum in these alkaloids displays a bathochromic shift of about 15 mμ. α-Obscurine (LXIX) has one maximum at 255 mμ (log ε 3.75).



LXVII



LXVIII



LXIX

2(1H)-Pyridones may have three different spectra depending on the pH of the solution (24).

In acid solution the aromatic system has an over-all positive charge, and the spectrum is similar to 2-ethoxypyridine, while in basic solution a proton can be lost to give the anion. The spectrum in neutral solution is found to be different from that of either acidic or basic solutions.

C. PIPERIDINES

Piperidine like other saturated six-membered heterocyclic compounds absorbs below 200 mμ and shows no absorption in the near-ultraviolet region. Some piperidine alkaloids, however, show ultraviolet spectra because of some other structural features. The hydrochloride of cassine (LXX) (189) shows λ_{max} at 276 mμ (log ε 1.52), and piperettine (LXXI), with an extended chromophore system, shows a broad band maximum at

TABLE IX

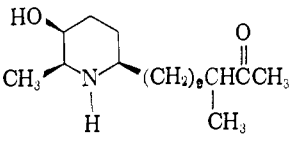
PYRIDINE, PYRIDONE, AND PIPERIDINE ALKALOIDS

Compound	$\lambda_{max.}$ mμ	Log ε	$\lambda_{min.}$ mμ	Log ε	Solvent[a]	Ref.
		Pyridines				
Anabasine	260	3.70	...	...	H^+ (0.8 *N*)	228
Anibine	228.5, 315, 254 sh	4.32, 4.09, 3.70	...	...	E	243
2,3-Dipyridine	237, 275	4.06, 4.00	253	3.8	E	217
Gentianine	220, 245 infl, 280	4.38, 3.9, 3.2	...	...	E	168
Homarine	278	3.7	...	...	E	
	272–273	3.8	...	...	H^+, OH^- (0.05 *N*)	194
Lycodine	267, 277 sh	3.72	...	...	M	8
Mimosine	282	4.28	...	...	W	2
Muscopyridine	213, 267	3.79, 3.61	...	...	E	51
Myosmine	234, 266	4.05, 3.58	214, 261	3.79, 3.58	E	324
	226, 262	3.79, 3.72	244	3.68	H^+	
Nicotine	262	3.46	232	3.01	E	
	260	3.80	231	3.00	H^+	324
Nicotyrine	288	3.99	251	3.62	E	
	244, 310	3.94, 4.03	226, 264	3.45, 3.30	H^+	324
N-Methylhalfordinium chloride	267, 360	4.17, 4.10	290	3.67	E	102
Nornicotine	262	3.46	233	3.02	E	324
	260	3.46	231	2.96	H^+	
Nornicotyrine	229, 294	3.78, 4.19	221, 251	3.74, 3.36	E	
	241, 316	3.97, 4.21	221, 259	3.44, 3.32	H^+	324
Pyridine	Main max. 257	3.43	...	...	E	217
Trigonelline	265, 272	3.6, 3.5	...	...	E	
	264, 272	3.6, 3.5	...	...	H^+, OH^- (0.5 *N*)	194
Wilforine	228, 270	4.35, 3.7	254	3.52	E	44
		Pyridones				
6-Methyl-2-pyridone	229, 304	3.87, 3.82	...	...	E	242
α-Obscurine	255	3.75	...	...	E	242
β-Obscurine	232, 315	3.98, 3.89	252	2.96	E	242
2-Pyridone	227, 297	4.00, 3.79	...	...	M	124
Ricinine	257, 315	3.54, 3.88	...	...	?	187
Selagine	231, 313	4.02, 3.92	...	...	E	330
		Piperidines				
Annotinine	325	1.25	...	...	E	45
Arecoline	214	4.02	...	...	E	229
Cassine hydrochloride	276	1.52	...	...	E	189
Isoorensine	222 ?	?	...	...	Eth	282
Julocrotine	252, 258, 264, 268	2.43, 2.44, 2.30, 2.18	...	...	E	245
Lyconnotine	235	4.3	...	...	E	9
Piperettine	364	4.65	...	...	E	313
Piperine	345	4.47	...	...	E	313
(±)-Sedamine	213, 252, 258, 264	3.70, 2.19, 2.28, 2.16	...	...	M	137
(−)-Sedinine	212, 252, 258, 264	3.72, 2.17, 2.27, 2.16	...	...	M	137
Tacomamine	226	4.10	...	...	E	203

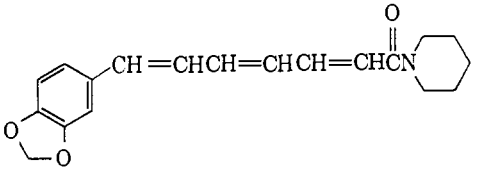
[a] See footnote in Table I for key to solvents.

364 mμ (log ε 4.65). Piperine (LXXII) exhibits a similar broad band with λ_{max} 345 mμ (log ε 4.47). Isoorensine (LXXIII) has an ultraviolet spectrum with λ_{max} at 222 mμ which is shifted to 261 mμ in acid, a fact in keeping with its α,β-unsaturated ketone structure (282).

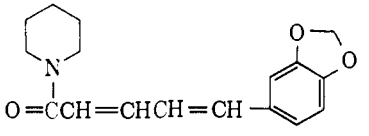
Julocrotine (LXXIV) has a piperidione structure, and the ultraviolet spectrum is due mainly to the benzene ring present. Catalytic hydrogenation shows the uptake of 3 moles of hydrogen, and the product is transparent in the ultraviolet. This is in agreement with an isolated benzene ring (245).



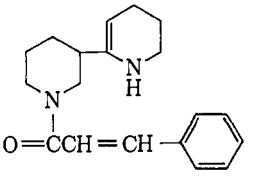
LXX



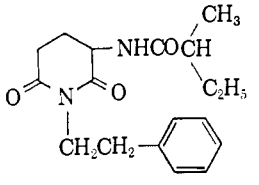
LXXI



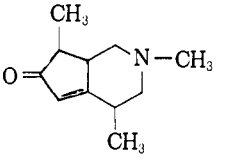
LXXII



LXXIII

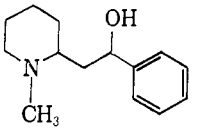


LXXIV

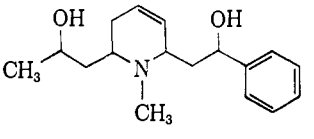


LXXV

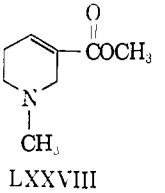
Tacomamine (LXXV), which has been degraded to a pyridine derivative, has λ_{max} 226 mμ (log ϵ 4.10) and in acidic ethanol shows a slight hypsochromic shift to 223 mμ (log ϵ 4.13) (203).



LXXVI



LXXVII



LXXVIII

(±)-Sedamine (LXXVI) and (−)-sedinine (LXXVII) have almost identical spectra and display fine structure at 252, 258, and 264 mμ (log ϵ 2.17–2.19, 2.27–2.28, and 2.16) owing to the aromatic ring. (−)-Sedinine can be contrasted with arecoline (LXXVIII) which has a carboxylic ester conjugated with the ring unsaturation and results in a strong maximum at 214 mμ (log ϵ 4.02).

The Lycopodium alkaloid lyconnotine with the novel structure LXXIX has a maximum at 235 mμ (log ϵ 4.3) and indicates a *transoid* diene (9).

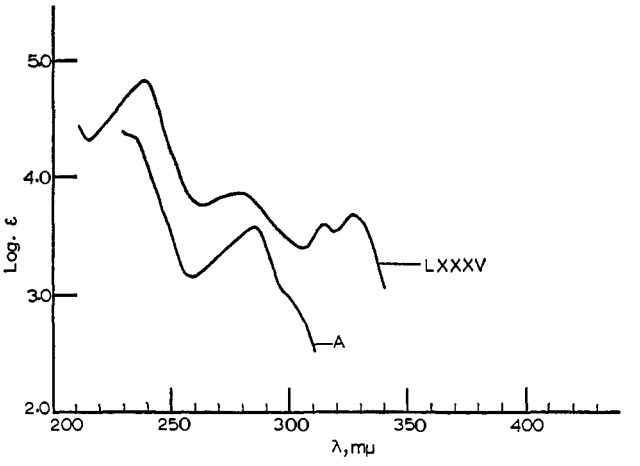
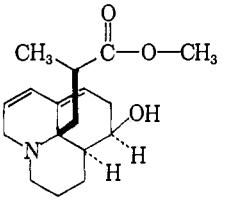


Figure 4.—Isoquinolines: 1,2,3,4-tetrahydroisoquinoline (A) in ethanol; papavarine (LXXXV) in ethanol.



LXXIX

X. ISOQUINOLINE GROUP

A large number of alkaloids have isoquinoline or extended isoquinoline ring systems. In most cases the heterocyclic ring is reduced. The protopines while not being strictly isoquinolines are included on biogenetic grounds.

For the purposes of this review the alkaloids can be classified as follows: (A) simple isoquinolines (including tetrahydroisoquinolines, pavine, benzylisoquinolines, bisbenzylisoquinolines, cularine, and rotundine); (B) morphine alkaloids; (C) aporphines and proaporphines; (D) erythrina alkaloids; (E) ipecacuanha alkaloids; (E) protopines; (G) phthalideisoquinolines; and (H) protoberberines.

A. SIMPLE ISOQUINOLINES

The simple isoquinolines can be classified structurally as follows: (1) tetrahydroisoquinolines including di- and triisoquinolines, (2) pavine type, (3) benzylisoquinolines, (4) bisbenzylisoquinolines, (5) cularine type, and (6) rotundine.

The term isoquinoline is often loosely used to denote the tetrahydroisoquinoline ring system. With the exception of papaverine all the alkaloids of these types are tetrahydroisoquinolines.

The ultraviolet spectra of these alkaloids are characteristic of one or more nonconjugated aromatic rings with maxima at ~285 mμ (log ϵ ~3.7); *cf.* tetrahydroisoquinoline (Figure 4). Where the aromatic rings are

TABLE X
SIMPLE ISOQUINOLINES

Compound	$\lambda_{max.}$ mμ	Log ε	$\lambda_{min.}$ mμ	Log ε	Solvent[a]	Ref.
1. Tetrahydroisoquinolines						
1,2,3,4-Tetrahydroisoquinoline hydroiodide	233 sh, 285, 298 sh	4.35, 3.58, 3.0	258	3.15	E	14
Lophocerine methyl ether	285	3.59	254	2.75	E	109
Pilocereine and pilocereidine	284	3.72	261	3.20	E	110
Pilocereine methyl ether	282, 320	2.68, 2.05	248, 310	3.16, 2.0	E	110
Pilocereine methiodide	284, 310, 278, 315 sh	3.65, 2.5, 3.85, 3.45	262 267	3.31 3.83	E E, OH^-	110 110
2. Pavine Type						
Pavine	225 sh, 288	4.22, 3.94	251	2.79	E	28
Argemonine	287	4.01	...	...	E	235, 315
3. Benzylisoquinolines (a) Tetrahydro Types						
Laudanine	224 sh, 283	4.18, 3.83	255	2.95	E	143, 255
Laudanosine	225 sh, 282	4.4, 3.78	...	...	E	138, 173
Laudanosine hydrochloride	280	3.51	...	...	E	138, 173
Magnocurarine	225, 282	4.12, 3.62	253	2.92	E	239
Norarmepavine	228, 282, 287	4.19, 3.70, 3.69	...	...	E	220
Pseudocodemine	284	3.78	...	...	E	143
Reticuline	285	...	...	...	E	161
(b) Unhydrogenated Isoquinolines						
Isoquinoline	263 sh, 268, 277 sh, 293 sh, 306, 313, 319	3.52, 3.55, 3.45, 3.16, 3.36, 3.35, 3.45	242, 290, 310, 315	3.26, 3.14, 3.30, 3.33	E	124, 215
	Practically unchanged				$E_{10\%}$, OH^- (0.01 *N*)	124, 215
	268 sh, 275, 283 sh, 329	3.27, 3.29, 3.11, 3.59	249, 290	2.95, 2.03	$E_{10\%}$, H^+ (0.01 *N*)	124, 215
Papavarine	239, 279–280, 314, 327	4.83, 3.86, 3.60, 3.67	215, 261, 305, 319	4.32, 3.77, 3.42, 3.54	E	255, 270
Papavarine hydrochloride	249–250, 280–282, 311	4.69, 3.80, 3.82	214, 269, 294	4.25, 3.74, 3.73	E	255
4. Bisbenzylisoquinolines						
Aromoline	285	3.88	262	3.64	M	48
Chondocurarine iodide	225, 280	4.79, 3.85	...	...	W	116
Chondodendrine dimethyl ether	280	4.20	262	4.05	Ch	307
Daphnandrine	285	3.91	259	3.33	M	48
Daphnoline (trilobamine)	285	3.93	261	3.68	M	48
Micranthine	286	3.73	261	3.48	M	50
Ocotine	285	3.68	...	...	?	173
Oxyocanthine	285	3.85	260	3.31	M	47, 48
Repandine	284	3.83	257	3.41	M	48
Rodiasine	287	3.95	...	...	?	173
Rodiasine hydrochloride	284	3.84	...	...	?	173
Sepeerine	284	3.79	...	...	E	173
Sepeerine hydrochloride	283	3.82	...	...	E	173
Tenuipine	282	3.82	...	...	E	49
Trilobine	288	3.75	261	3.48	M	47
Tubocurarine chloride	225, 280	4.79, 3.85	...	...	W	116
5. Cularine Type						
Cularine	226, 285	4.38, 3.92	...	...	E	204
6. Rotundine Type						
Rotundine	288	3.8	250	2.9	E	210

[a] See footnote in Table I for key to solvents.

joined through an oxygen atom, the spectra are not very different from nonconjugated-type spectra, indicating that the benzene rings are not significantly coupled. Papavarine with an isoquinoline ring and a nonconjugated benzene ring is more complex, and the spectrum is similar to that of isoquinoline.

Examples of the above types are discussed below and spectral data are summarized in Table X.

TABLE XI

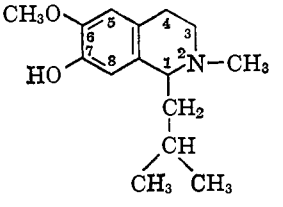
MORPHINE ALKALOIDS

Compound	$\lambda_{max.}$ mμ	Log ε	$\lambda_{min.}$ mμ	Log ε	Solvent[a]	Ref.
(i)						
Codeine	211, 239 sh, 286	4.38, 3.67, 3.19	263	2.73	E	255
Morphine	233 sh, 285	3.71, 3.18	263	2.67	E	255
Morphine hydrochloride	209, 232 sh, 285	4.42, 3.70, 3.19	261	2.69	W	255
Morphine	226, 248 sh, 299	4.04, 3.73, 3.44	273	3.2	M, OH^-	38
Neopine hydrobromide (β-codeine)	299 sh, 284	3.87, 3.17	258	2.58	W	255
(ii)						
Thebaine	226 sh, 285	4.18, 3.87	256	3.51	E	255
(iii)						
Sinomenine hydrochloride	232, 265	3.83, 3.72	227, 248	3.81, 3.65	W	255
(iv)						
Pseudomorphine	230–232, 257 sh, 285 sh	4.56, 3.98, 364	218	4.44	E, H^+ (0.2 *N*)	38, 255
Pseudomorphine	230, 306	4.56, 3.96	281	3.80	M, OH^-	38

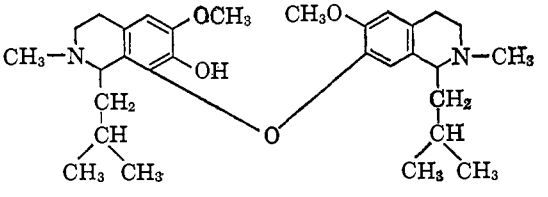
[a] See footnote in Table I for key to solvents.

1. *Tetrahydroisoquinolines*

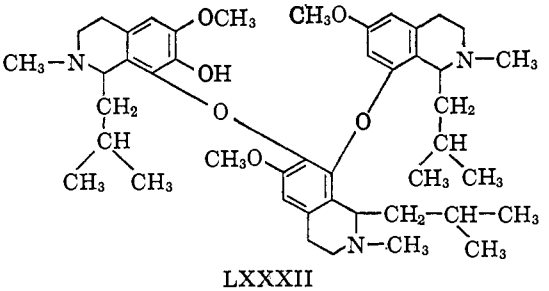
Examples are the alkaloids lophocerine (LXXX), isopilocereine (LXXXI), and pilocereine[1] (LXXXII).



LXXX



LXXXI

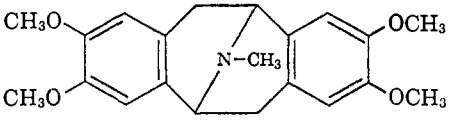


LXXXII

2. *Pavine Type*

The alkaloid argemonine (LXXXIII) originally included with the aporphines (233) has recently been shown to be N-methylpavine (235, 315). Pavine, a well-known transformation product of papaverine, has been synthesized (28), but the isolation of the N-methyl derivatives from natural sources illustrates a new type of naturally occurring ring system.

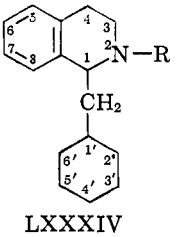
(1) Revised structure by Djerassi in ref. 107.



LXXXIII

3. *Benzylisoquinolines*

The alkaloids of this group are practically all benzyltetrahydroisoquinolines, *e.g.*, LXXXIV, so that although the spectra of quinolines and isoquinolines show marked differences (124), these differences are usually of little diagnostic value as most isoquinoline alkaloids occur as tetrahydro derivatives with maxima at ~283 mμ (log ε ~3.7).



LXXXIV

	R	3′	4′	6	7
Laudanine	CH_3	OH	OCH_3	OCH_3	OCH_3
Laudanosine	CH_3	OCH_3	OCH_3	OCH_3	OCH_3
Magnocurarine	CH_3, CH_3[a]	...	OH	OCH_3	OH
Norarmepavine	H	...	OH	OCH_3	OCH_3
Pseudocodemine	CH_3	OCH_3	OH	OCH_3	OCH_3
Reticuline	CH_3	OH	OCH_3	OCH_3	OH

[a] Quaternary salt.

Papavarine (LXXXV) is an example of an unhydrogenated isoquinoline and has a fairly complex spectrum, with three main regions of absorption at 238 (log ε 4.8), 279 (386); and 313–327 mμ (~3.6) (see Figure 4).

The variation of the wave length and absorptivity values of the 238-mμ band with pH have been studied (136).

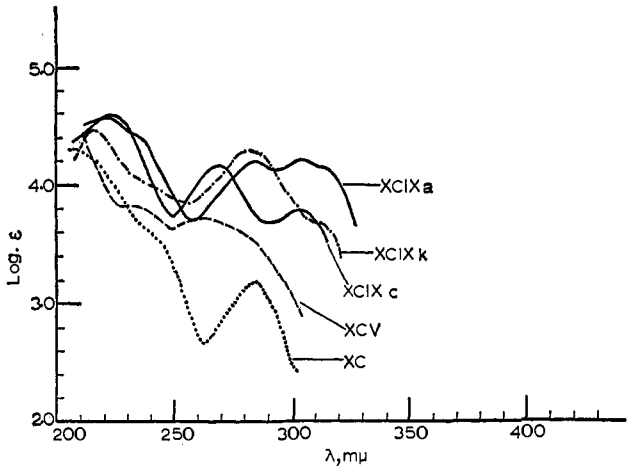
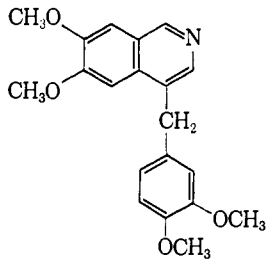


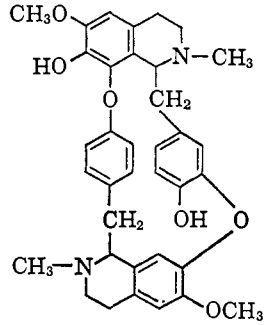
Figure 5.—Isoquinolines (morphines and apomorphines): morphine (XC) in ethanol; sinomenine (XCV) hydrochloride in water; boldine (XCIXa) in methanol; isocorydine (XCIXc) hydrobromide in methanol; xylopine (XCIXk) in ethanol.



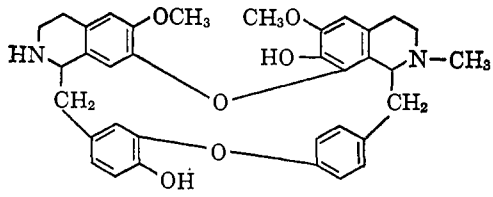
LXXXV

4. *Bisbenzylisoquinolines*

There are a large number of types of these alkaloids depending on the points of attachment of the various aromatic rings, but their spectra are quite similar with maxima at ~283 mμ (log ε ~3.8). Examples are tubocurarine (LXXXVI) and daphnoline (LXXXVII). Spectral data for other members of this group are summarized in Table X.



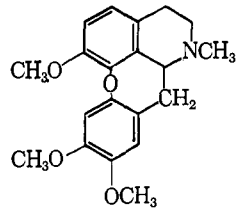
LXXXVI



LXXXVII

5. *Cularine Type*

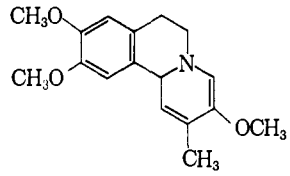
The spectrum of cularine (LXXXVIII), with maxima at 226 (log ε 4.38) and 285 mμ (3.92) (204), is similar to that of the simple benzoid systems previously mentioned.



LXXXVIII

6. *Rotundine*

Rotundine (LXXXIX) is the only known alkaloid of this type and shows a simple ultraviolet spectrum with a maximum at 288 mμ (log ε 3.8) (210).



LXXXIX

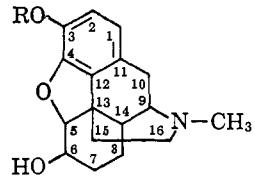
B. MORPHINE ALKALOIDS

The morphine group of alkaloids may be classified as follows: (1) morphine type (aromatic ring plus an isolated double bond), (2) thebaine type (aromatic ring plus nonconjugated 1,3-dione), (3) sinomenine type (aromatic ring plus nonconjugated α,β-unsaturated ketone), (4) dimeric types (substituted diphenyl and nonconjugated diene or enone), and (5) dienone types (aromatic ring plus nonconjugated dienone system).

The spectra of a number of morphine alkaloids and their degradation products have been summarized (35, 36) (see Table XI).

1. *Morphine Type*

The spectra of this group (XC) are simple uncon-

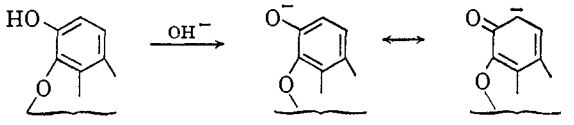


XC

		R	Double bond
a	Codeine	CH_3	7:8
b	Morphine	H	7:8
c	Neopine (β-codeine)	CH_3	8:14

jugated aromatic types with maxima at 285 mμ (log ε ~3.2) (Figure 5). The spectra are unchanged in acid,

but morphine shows a bathochromic shift in alkali associated with the ionization of the phenol (XCI →

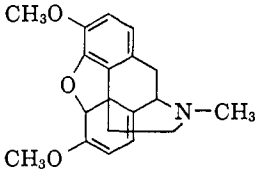


XCI XCII XCIII

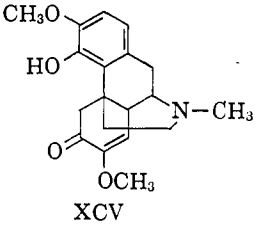
XCIII). The shift of ~14 mμ is consistent with the shifts obtained for unhindered phenols (93).

2. *Thebaine Type*

Thebaine (XCIV) has a maximum at 285 mμ (log ε 3.87) with higher absorbance values than morphine. The 1,3-diene system enhances the intensity of the spectrum at lower wave lengths.



XCIV



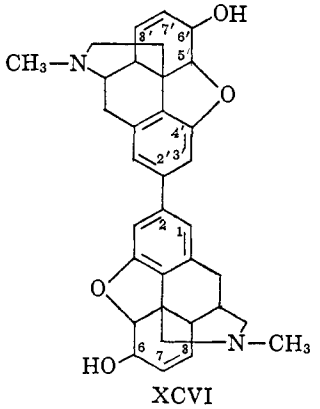
XCV

3. *Sinomenine Type*

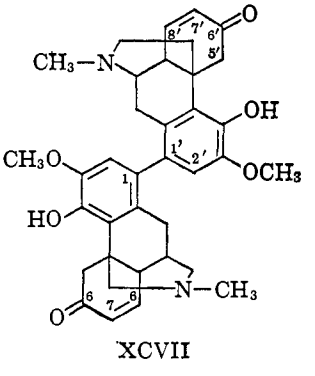
These alkaloids have an α,β-unsaturated ketone system isolated from the aromatic ring. The spectrum of sinomenine (XCV) is characterized by a maximum at 232 mμ (log ε 3.83) and a broad band at 265 mμ (log ε 3.72) (255) (Figure 5).

4. *Dimeric Types*

The dimeric morphine (pseudomorphine) (XCVI) and sinomenine (disinomenine) (XCVII) coupled at positions 2–2′ and 1–1′, respectively, now have an extended diphenyl chromophore, and the spectrum bears evidence of this. Pseudomorphine has a maximum at 321 mμ with shoulders at 257 and 285 mμ, the latter being shifted to 306 mμ in the alkali (38).



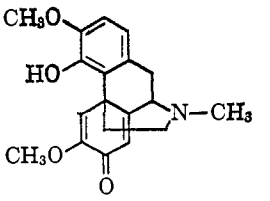
XCVI



XCVII

5. *Dienone Types*

The dienone system (XCVIII), recently synthesized (26), also exists naturally in small quantities in the

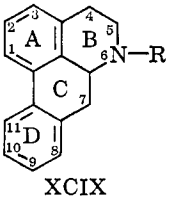


XCVIII

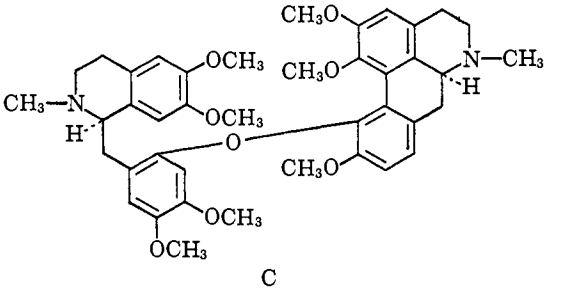
Papavaceae.[2] The ultraviolet spectrum has not been reported, but it might be expected to show similarities to the proaporphines (see below).

C. APORPHINES AND PROAPORPHINES

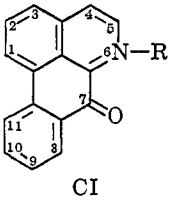
The aporphines can be subdivided into the following chemical types: (1) the aporphines and noraporphines (XCIX), (2) aporphine–benzyltetrahydroisoquinoline (C), (3) oxyaporphines (CI), and (4) proaporphines (CII). The ultraviolet spectra of these types can be of great diagnostic value.



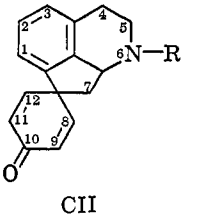
XCIX



C



CI



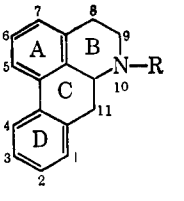
CII

1. *Aporphines*[3] *and Noraporphines*[4]

It is convenient to classify the simple aporphines into three main ultraviolet types, the spectra being more

(2) Private communication from Professor A. R. Battersby.

(3) Ring numbering in structure XCIX is that in the "Ring Index" (see ref. 306); other common numbering used is



(4) The termination nor is restricted to des-N-methyl (see ref. 336).

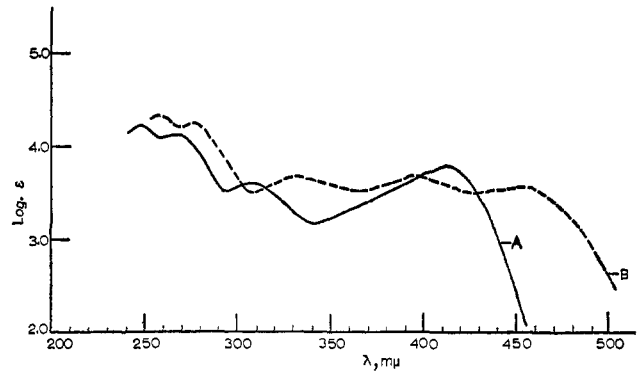
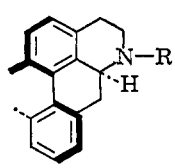


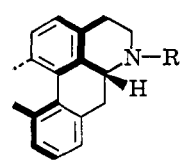
Figure 6.—Isoquinolines (oxyaporphines): (A) liriodenine (Cl, 1,2-methylenedioxy) in ethanol; (B) liriodenine hydrochloride in ethanolic 0.1 *N* hydrochloric acid.

markedly dependent on the position of the substituent rather than on the nature of the substituent. The spectra may be regarded as derived from the basic biphenyl system with the added influence of several auxochromes. Biphenyl has a maximum at 264 mμ and 2-methylbiphenyl has maxima at 245 and 282 mμ (140). When positions 10 and 11 are unsubstituted (aporphine-type (XCIX) (R = CH_3)) the spectra show one peak at 270–280 mμ (log ε ~4.3) and a shoulder or smaller peak at 310–320 mμ (log ε ~3.3) (see Figure 5). Most of the aporphine alkaloids are substituted at positions 10 or 11, and all the known alkaloids are invariably substituted at positions 1 and 2 (37). (Argemonine was incorrectly assigned a 2,3-dimethoxy structure (310), but was later shown not to be an aporphine alkaloid (see LXXXIII).) It was recognized (302, 305) that the spectra of the other aporphines fall into two characteristic types having maxima at 220 mμ and two in the region 270–310 mμ. The shapes of the curve and the intensity of the latter two maxima depend on the substitution in ring D.

Alkaloids with position 11 free (boldine type (XCIXa), Table XII) show maxima at 282 and 303–310 mμ of about equal intensity (log ε ~4.2) (see Figure 5). The spectrum of michepressine (XCIXl) is anomalous. Alkaloids with position 11 substituted (corydine type, Table XII) show maxima at 268–272 mμ (log ε ~4.2) and another maximum with lowered intensity at 303–310 mμ (log ε ~3.8) (Figure 5). These differences have been related to the degree of strain in the biphenyl system. X-Ray analysis of the alkaloid bulbocapnine (15) shows that the biphenyl ring is appreciably strained.



CIII
α-H (*S*-series)



CIV
β-H (*R*-series)

The alkaloids can exist in two conformational forms (CIII and CIV).

Optical rotatory dispersion studies have also been used to confirm the substitution pattern (112), and the studies appear to confirm the assumption (37) that a positive specific rotation at the D-line (589 mμ) is associated with the configuration CIII. The spectra of the aporphines are unchanged in acid, but in basic solution the phenolic aporphines undergo a significant bathochromic shift (see 3,5-dihydroxy-6-methoxyaporphine). Examples of the three types of aporphine are shown in Table XII, and spectral data are summarized in Table XIIA (*cf.* Figure 5).

2. *Aporphine–Benzyltetrahydroisoquinoline (Dimeric Aporphines)*

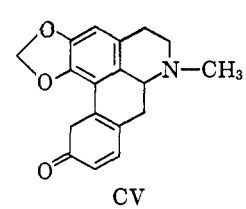
The spectrum of thalicarpine (221), the only member of the group recognized so far, has maxima at 282 (log ε 4.23) and 302 mμ (4.11). The spectrum is more like that of the 11-unsubstituted than of the 11-substituted aporphines.

3. *Oxyaporphines*

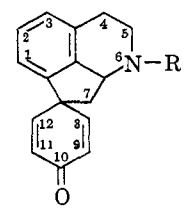
The yellowish colored alkaloids possess a highly unsaturated chromophoric system with extended absorption in the ultraviolet and visible. Liriodenine (CI) (1,2-methylenedioxy) (Figure 6) shows three main absorption bands at 245–270 (log ε 4.1), 309 (3.6), and 413 mμ (3.8) (73). On acidification, the spectrum is shifted to longer wave lengths with a series of undulating maxima between 325 and 460 mμ (log ε ~3.5).

4. *Proaporphines*

A number of alkaloids of this type have recently been isolated and characterized. The alkaloids show two main maxima at 230 (log ε ~4.4) and 290 mμ (~3.5), with occasional splitting of the peaks. The spectra of the proaporphine system (CII) have been shown to be consistent with the addition of the spectra of homoveratrylamine and 4-methyl-3-allylcyclohexa-2,5-dien-1-one (41). The 290-mμ band shows a bathochromic shift in alkali. The known proaporphines rearrange to



CV



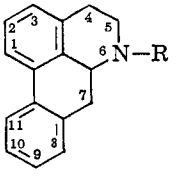
CII

		R	1	2
a	Crotonosine[a]	H	OCH_3	OH
b	Fugapavine[b]	CH_3	$-OCH_2O-$	
c	Glaziovine	CH_3	OH	OCH_3
d	Pronuciferine	CH_3	OCH_3	OCH_3
e	Stepharine	H	OCH_3	OCH_3

[a] This structure has been confirmed (180, 181). [b] Speculative structure.

TABLE XII

TYPES OF APORPHINES



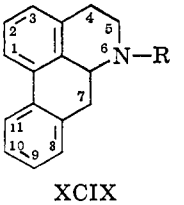
XCIX

Aporphine Type. Positions 10 and 11 Free

Structure XCIX	R	Substituent 1	2	7	8	9
a Aporphine	CH_3	...	...	...	...	...
b Apomorphine	CH_3	...	...	...	OH	OH
c Crebanine	CH_3	$-OCH_2O-$		...	OCH_3	OCH_3
d Noraporphine	H	...	...	...	...	...
e Nornuciferine	H	OCH_3	OCH_3	...	...	...
f Norushinsunine	H	$-OCH_2O-$		OH	...	...
g Nuciferine	CH_3	OCH_3	OCH_3	...	...	...
h Roemerine (N-methylanonaine)	CH_3	$-OCH_2O-$		...	...	...
i Stephanine	CH_3	$-OCH_2O-$		...	OCH_3	...
j Ushinsunine	CH_3	$-OCH_2O-$		OH	...	...
k Xylopine	H	$-OCH_2O-$		...	...	OCH_3

Boldine Type. Position 11 Free

	R	1	2	8	9	10
a Boldine	CH_3	OCH_3	OH	...	OH	OCH_3
b Cocsarmine	CH_3, CH_3[a]	OCH_3	OCH_3	...	OCH_3	OH
c Crebanine	CH_3	$-OCH_2O-$		OCH_3	OCH_3	...
d Dicentrine	CH_3	$-OCH_2O-$		...	OCH_3	OCH_3
e Domesticine	CH_3	OH	OCH_3	...	$-OCH_2O-$	
f Glaucine	CH_3	OCH_3	OCH_3	...	OCH_3	OCH_3
g 2-Hydroxy-1,9,10-trimethoxyaporphine	CH_3	OCH_3	OH	...	OCH_3	OCH_3
h Laurelliptine	H	OCH_3	OH	...	OCH_3	OH
i Laurifoline	CH_3, CH_3[a]	OH	OCH_3	...	OH	OCH_3
j 2-Methoxyapomorphine	CH_3, CH_3[a]	...	OCH_3	...	...	...
k N-Methyllaurotetanine	CH_3	OCH_3	OCH_3	...	OCH_3	OCH_3
l Michepressine (laureline methosalt)	CH_3, CH_3[a]	$-OCH_2O-$		...	...	OH
m Octoteine[b] (thalicmine)	CH_3	$-OCH_2O-$		...	OCH_3	OCH_3
n Phanostenine	CH_3	$-OCH_2O-$		...	OCH_3	OH



XCIX

Corydine Type. Position 11 Substituted

	R	1	2	8	9	10	11
a Bulbocapnine	CH_3	$-OCH_2O-$		...	...	OCH_3	OH
b Corydine	CH_3	OH	OCH_3	...	...	OCH_3	OCH_3
c Isocorydine	CH_3	OCH_3	OCH_3	...	...	OCH_3	OH
d N-Methylisocorydinium methosalt (menisperine)	CH_3, CH_3[a]	OCH_3	OCH_3	...	...	OCH_3	OH
e Norisocorydine	H	OCH_3	OCH_3	...	...	OCH_3	OH
f Pseudocorydine	CH_3	OCH_3	OCH_3	...	...	OH	OCH_3
g Pukateine	CH_3	$-OCH_2O-$		...	...	...	OH

[a] Quaternary salt. [b] Structure may be modified.

aporphines on acid treatment, the latter having the characteristic 11-unsubstituted aporphine spectra (154). Fugapavine has been assigned the aporphine structure CV (241), which is unlikely as this compound would exist as the phenolic form. It has been speculated (154) that the alkaloid is also a proaporphine of structure CIIb. The suggestion (306) that fugapavine and mecambrine are identical seems unlikely as the ultraviolet spectra recorded for these two compounds are quite different.

TABLE XIIA
APORPHINES AND PROAPORPHINES

Compound	λ_{max}, mμ	Log ε	Solvent[a]	Ref.
	Aporphines			
Apomorphine hydrochloride	211, 225 sh, 272, 278 sh, 301 sh	4.51, 4.20, 4.21, 4.05, 2.78, 3.48	W	255
Apomorphine dimethyl ether	271, 298 sh	4.24, 3.61	?	323
Aporphine hydrochloride	270, 282 sh	4.27, 4.19	E	335
Boldine	220, 232 sh, 284, 303, 313 sh	4.6, 4.47, 4.2, 4.23, 4.16	M	287
Bulbocapnine	233, 270, 308	4.07, 3.9, 3.6	?	164
Cocsarmine iodide	282, 308	4.11, 4.22	?	306
Corydine	270, 309	4.15, 3.82	E	14
Crebanine	280, 308 sh	4.29, 3.8	E	167
Dicentrine	282, 310	4.2, 4.3	?	305
1,10-Dihydroxy-2-methoxyaporphine	218, 266, 275, 307	4.58, 4.01, 4.13, 3.96	E	154
	Unchanged		B (boric acid)	154
	340	3.98	E, OH^-	154
Domesticine	220, 281, 308 (λ_{min} 225, 288)	4.67, 4.08, 4.23 (3.74, 3.99)	?	49
Glaucine	218, 280–282, 302	4.58, 4.18, 4.16	E	94
1-Hydroxy-2-methoxyaporphine	271, 310	4.14, 3.59	E	154
2-Hydroxy-1,9,10-trimethoxy-N,N-dimethylapomorphinium chloride	228, 271 sh, 281, 307, 321 sh	4.60, 4.02, 4.12, 4.21, 4.06	E	283
	250 sh, 265–70 sh, 347	4.40, 4.29, 4.19	E, OH^- (0.3 N)	283
2-Hydroxy-1,9,10-trimethoxy-N,N-dimethylapomorphinium hydroxide	228, 270 sh, 281, 307, 321 sh	4.57, 4.00, 4.10, 4.18, 4.04	E	283
Isocorydine hydrobromide (artabotrine)	220, 268, 302	4.6, 4.18, 3.8	M	287
Isocorydine methochloride (N-methylisocorydine chloride)	217, 267, 300	4.62, 4.16, 3.76	W:E (10:1)	208
Isocorydine methochloride (N-methylisocorydine chloride) (chakranine)	225, 343	4.53, 3.89	W (pH 13)	208
Isothebaine methyl ether	273, 302	4.1, 3.92	?	37, 109
Laurelliptine	280, 305	3.70, 3.76	E	92
Laurefoline chloride	227, 281, 307	4.48, 4.04, 4.14	?	305
Menispermine chloride	223, 270, 303	4.6, 4.13, 3.76	?	305
N-Methyllaurotetanine hydrobromide	221, 284, 305, 311 sh	3.64, 4.16, 4.20, 4.14	E	287
Michepressine iodide	273, 316	4.14, 3.60	?	306
Morphothebaine	273, 300	4.2, 3.87	E	35
Nantenine	284, 310	4.0, 4.1	?	306
Noraporphine	271	4.26	?	306
Norisocorydine	222, 270, 305	4.6, 4.18, 3.82	E	287
Nornuciferine	230, 272, 310	4.31, 4.23, 3.34	E	220
Nornuciferine hydrochloride	231, 270, 310	4.35, 4.25, 3.36	E	336
Norushinsunine	275, 328	4.23, 3.49	?	306
Nuciferine	230, 272, 310	4.26, 4.19, 3.32	E	220
Ocoteine (thalicmine)	283, 302	4.25, 4.25	E	331
Phanostenine	221, 281, 309	4.48, 4.14, 4.19	?	306
Pseudocorydine	272, 302	4.04, 3.66	E	144
Pseudocorydine hydrochloride	272, 302	4.09, 3.70	E	144
Pukatein hydrochloride	218, 272, 303	4.42, 4.10, 3.95	?	300
Roemerine hydrochloride (N-methylanonaine)	235, 272, 315	4.19, 4.27, 3.59	?	306
Stephanine	272	4.28	?	306
Ushinsunine	274, 321	4.21, 3.51	?	306
Xylopine	214, 230 sh, 282, 307 sh (λ_{min} 257)	4.49, 4.15, 4.33, 3.74 (3.87)	E	302
	Aporphine–Benzyltetrahydroisoquinoline			
Thalicarpine	282, 302	4.23, 4.11	M	221

Compound	λ_{max}, mμ	Log ε	λ_{min}, mμ	Log ε	Solvent	Ref.
	Oxyaporphines					
Liriodenine	247, 268, 309, 413	4.22, 4.13, 3.62, 3.82	258, 292, 340, 455–700	4.08, 3.51, 3.16, 0.0	E	73
Liriodenine	257, 277, 329, 392, 455	4.33, 4.26, 3.67, 3.69, 3.58	269, 307, 362, 426, 545–700	4.20, 3.53, 3.55, 3.52, 0.00	E, H^+ (0.1 N)	73

TABLE XIIA (*Continued*)

Compound	λ_{max}, mμ	Log ε	λ_{min}, mμ	Log ε	Solvent	Ref.
1,2,9,10-Tetramethoxydibenz-[*de*, *g*]quinolin-7-one	242, 272, 355, 376–382	4.52, 4.53, 3.99, 3.90	249, 290	3.77, 3.7	E	94
		Proaporphines				
Crotonosine	216, 235, 282, 290	4.31, 4.33, 3.37, 3.41	223, 232, 273, 286	4.30, 4.28, 3.24, 3.35	E	179
Fugapavine[b]	222, 266, 274, 307	4.5, 4.2, 4.23, 4.0	...	...	E	241
Glaziovine	288	3.57	...	...	E	154
Glaziovine	308	3.74	...	...	E, OH^-	154
Mecambrine[b]	231, 294	4.5, 3.7	...	...	?	306
Pronuciferine	230, 280, 285, 305 sh	4.46, 3.55, 3.55, 2.92	274, 283	3.49, 3.51	E	179
Stepharine	213, 231, 284	4.62, 4.44, 3.48	225, 274	4.43, 3.45	E	77
Tetrahydroglaziovine	286	3.42	...	...	E	154
Tetrahydroglaziovine	253, 299	3.79, 3.65	...	...	E, OH^-	154

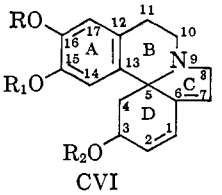
[a] See footnote in Table I for key to solvents. [b] Structure uncertain.

D. ERYTHRINA ALKALOIDS

The erythrina alkaloids can be classified as follows: (1) aromatic types (erysodine type and erythramine type), and (2) erythroidines.

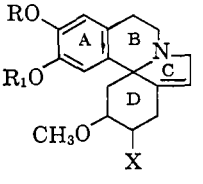
1. *Aromatic Types*

The aromatic types differ in that in the erysodine type CVI possesses a diene system isolated from the aromatic molecule. The erythramine type (CVII) has one of the double bonds saturated. Both types show maxima at ~235–240 (log ε 3.9–4.2) and ~285–290 mμ (log ε 3.6). Alkaloids with phenolic hydroxyl show a typical bathochromic shift in alkaline solution (267).



CVI

		R	R_1	R_2
a	Erysodine	H	CH_3	CH_3
b	Erythraline	$-CH_2-$		CH_3



CVII

		R	R_1	X
a	Dihydroerysodine	H	CH_3	H
b	Dihydroerythraline (erythramine)	$-CH_2-$		H
c	Erythratine	$-CH_2-$		OH

The aromatic alkaloids on acid treatment are demethylated at C_3 and can then be dehydrated (*e.g.*, apoerysodine (CVIII)). The latter compounds show a bathochromic shift owing to the additional double bond. Stronger acid treatment (HBr) results in an expansion of ring B giving rise to a substituted biphenyl system (*e.g.*, apoerysopine (CIX) (Figure 7)).

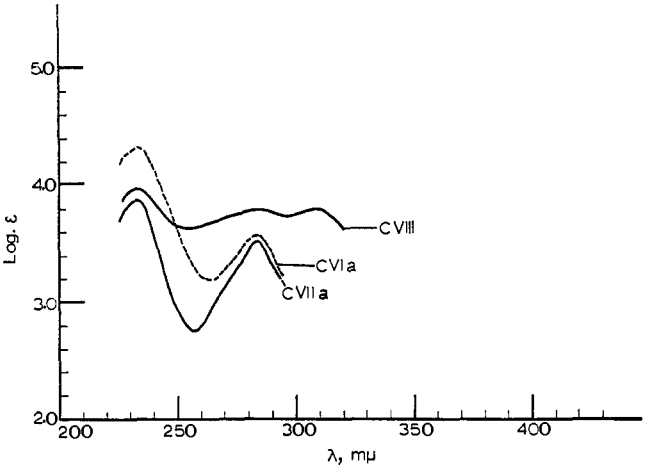
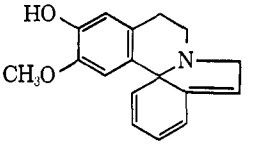
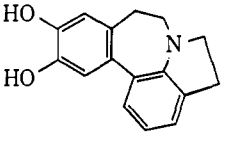


Figure 7.—Isoquinolines (erythrina group): erysodine (CVIa) in ethanolic 0.01 *N* hydrochloric acid; dihydroerysodine (CVIIa) in ethanolic 0.01 *N* hydrochloric acid; apoerysodine (CVIII) in ethanol.



CVIII



CIX

2. *Erythroidines*

The α- and β-erythroidines differ in the position of a double bond. In α-erythroidine (CX) the double bond is conjugated with the carbonyl group. In β-erythroidine (CXI) the double bond is not conjugated. Thus α-erythroidine has a somewhat higher absorbance than the β-isomer (see Figure 8).

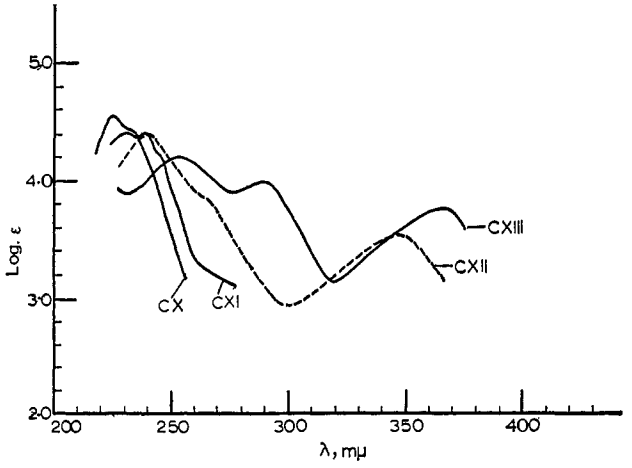
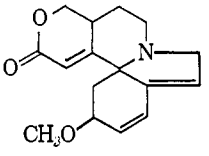
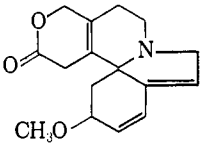


Figure 8.—Isoquinolines (erythrina group): α-erythroidine (CX) hydrochloride in ethanol; β-erythrodine (CXI) hydrochloride in ethanol; apo-β-erythroidine (CXII) in ethanol; isoapo-β-erythroidine (CXIII) in ethanol.

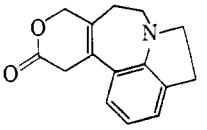


CX

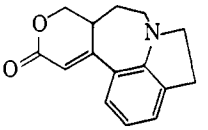


CXI

The α- and β-erythroidines also show the ring expansion shown by the aromatic types. β-Erythroidine on treatment with concentrated HBr is converted to the apo-β-erythroidine (CXII) and isoapo-β-erythroidine (apo-α-erythroidine) (CXIII).



CXII



CXIII

Isoapo-β-erythroidine (CXIII) has extended conjugation between the aromatic ring and the lactone carbonyl, is yellow, and has a maximum beyond 360 mμ (53). Examples of the erythrine group of alkaloids are summarized in Table XIII (*cf.* Figure 8).

E. IPECACUANHA ALKALOIDS

There are a number of structurally related bases in this group with varying degrees of unsaturation. The group may be subdivided into the following types: (1) protoemetine–emetine group, (2) psychotrine group, and (3) emitamine group. These relationships are illustrated in structures (CXIVa–g).

TABLE XIII

ERYTHRINA ALKALOIDS

Compound	λ_{max}. mμ	Log ε	λ_{min}. mμ	Log ε	Solvent[a]	Ref.
	Aromatic Alkaloids and Derivatives					
Apoerysodine	234, 288, 307–312	3.99, 3.79, 3.79	253, 297	3.65, 3.75	E	76
Apoerysopine	232, 276, 301	4.20, 3.96, 3.96	226, 254	4.17, 3.65	E, H^+ (0.01 *N*)	76
Apoerythraline hydrobromide	238 sh, 295	3.86, 3.74	261	3.38	W	76
Dihydroerysodine	234, 285	3.88, 3.54	257	2.77	E, H^+(0.01 *N*)	267
	253, 300	3.96, 3.68	235, 278	3.76, 3.33	E, OH^- (0.01 *N*)	267
Dihydroerythraline (erythramine)	241, 291	3.65, 3.65	260	2.82	E, H^+(0.01 *N*)	267
	241, 291	3.65, 3.67	260	2.86	E, OH^- (0.01 *N*)	
Erysodine	235, 285	4.32, 3.57	264	3.2	E, H^+(0.01 *N*)	267
	230–240 sh, 297	4.28, 3.71	279	3.6	E, OH^- (0.01 *N*)	
Erythraline	238, 290	4.29, 3.66	264	3.11	E, H^+(0.01 *N*)	267
	225, 273 sh, 290	4.16, 3.23, 3.59	272	3.46	E, OH^- (0.01 *N*)	
Erythratine	294	3.63	260	2.85	E	134
Tetrahydroerysodine	284	3.71	255	3.0	E, H^+(0.01 *N*)	267
	246, 299	3.94, 3.68	231	3.78	E, OH^- (0.01 *N*)	
Tetrahydroerythraline	291	3.65	...	...	E, H^+(0.01 *N*)	267
	Erythroidines and Derivatives					
Apo-β-erythroidine	240, 267 sh	4.39, 3.81	300	2.93	E	53
	343–348	3.54				
Isoapo-β-erythroidine	254, 290	4.21, 4.0, >3.7	231	3.89	E	53
	>360		276	3.90		
			319	3.14		
α-Erythroidine hydrochloride	229	4.54	...	...	E	52
	232 sh	4.46				
β-Erythroidine hydrochloride	232, 240	4.4, 4.4	236	4.38	E	53
	245 sh	4.27, 3.28				
	264 sh					

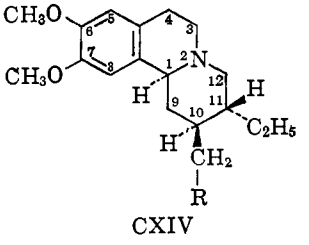
[a] See footnote in Table I for key to solvents.

TABLE XIV

IPECACUANHA ALKALOIDS

Compound	$\lambda_{max.}$ mμ	Log ε	$\lambda_{min.}$ mμ	Log ε	Solvent[a]	Ref.
		Alkaloids				
Emetamine	236, 283 314, 327	4.85, 3.86 3.52, 3.58	217, 262, 303, 321	4.28, 3.72, 3.36, 3.48	E	29
Emetine dihydrochloride	230, 283	4.23, 3.87	256	3.11	E	66, 67, 122
Isoemetine	233, 285	4.19, 3.45	...	...	E	66
O-Methylpsychotrine hydrogen oxalate	241, 290, 305, 360	4.25, 3.85, 3.92, 3.94	260, 288, 333	3.66, 3.83, 3.57	E	66, 256
Protoemetine perchlorate	232, 283	3.92, 3.61	220, 254	3.85, 2.68	E	30
		Degradation Products				
2-Dehydroemetine	232, 284	4.18, 3.86	...	...	E	65
2-Dehydroisoemetine	232, 284	4.20, 3.87	...	...	E	65
2-Dehydro-O-methylpsychotrine	236, 292, 306, 358	4.27, 3.96, 3.97, 3.91	...	...	E	65
Rubremetamine bromide	256, 299, 330, 372, 461	4.61, 3.97, 3.93, 3.93, 4.22	227, 282, 321, 342, 404	4.25, 3.92, 3.86, 3.76, 3.74	W	206
Rubremetine chloride	257, 286 300, 437	4.28, 4.24 4.26, 4.47	...	...	W	67
Rubremetine bromide	258, 288, 300, 379 sh, 438	4.21, 4.22, 4.22, 4.02, 4.40	243, 272, 292, 332	4.12, 4.08, 4.20, 3.79	W	23, 206
Tetradehydroemetine hydrogen oxalate	245, 308, 358	4.41, 4.17, 4.17	270, 340	3.72, 4.07	W	34
Tetradehydroisoemetine	244, 308, 360	3.47, 4.22, 4.27	265, 330	3.15, 4.03	W	182

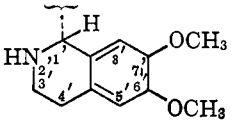
[a] E = ethanol (95%–absolute); W = water.



CXIV

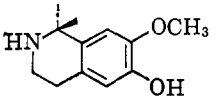
a Protoemetine R = CHO

b Emetine

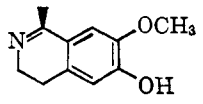


c Isoemetine (reverse configuration at C-1′)

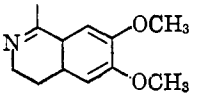
d Cephaeline



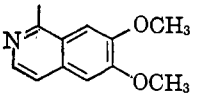
e Psychotrine



f O-Methylpsychotrine



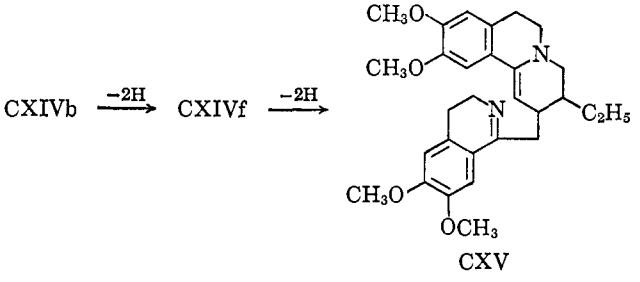
g Emetamine



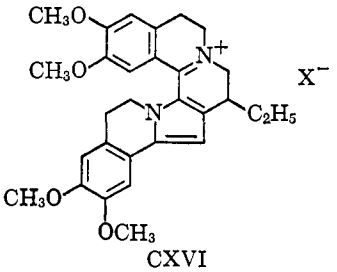
The alkaloids are also related through a series of common degradation products (see Table XIV).

1. *Protoemetine–Emetine Group*

The spectra of these alkaloids are quite simple with maxima at ~230 and 280 mμ associated with one or two nonconjugated aromatic rings. All the ipecacuanha alkaloids are readily dehydrogenated. Emetine (CXIVb) is dehydrogenated in a series of stages through O-methylpsychotrine (CXIVf), tetradehydroemetine (CXV) to the red rubremetinium salts (CXVI).



CXV



CXVI

With increasing unsaturation in the dehydrogenation series, the spectra become more complex (see Figure 9). The spectra of a number of synthesized stereoisomers of emetine and isoemetine are essentially the same as emetine (66).

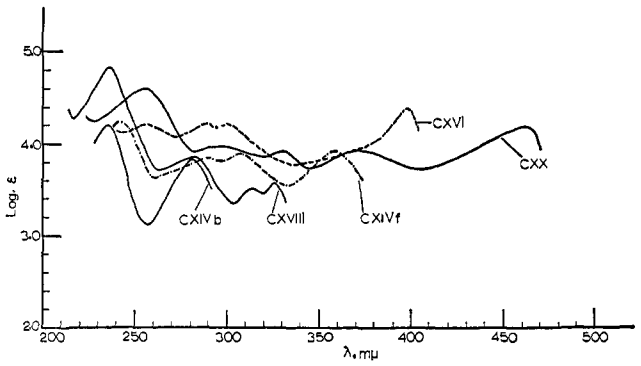


Figure 9.—Isoquinolines (ipecacuanha group): emitamine (CXVIII) in ethanol; emetine (CXIVb) dihydrochloride in ethanol; O-methylpyschotrine (CXIVf) hydrogen oxalate in ethanol; rubremetine (CXVI) bromide in water; rubremetamine (CXX) bromide in water.

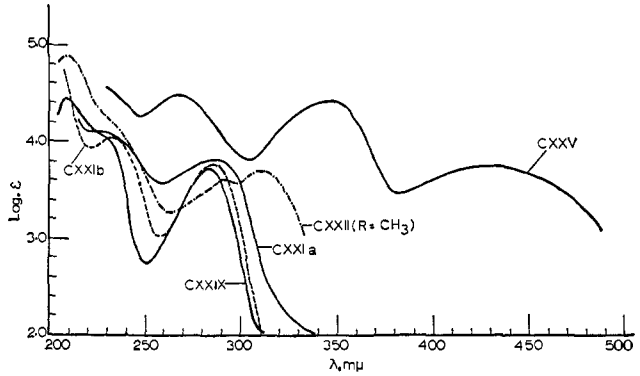


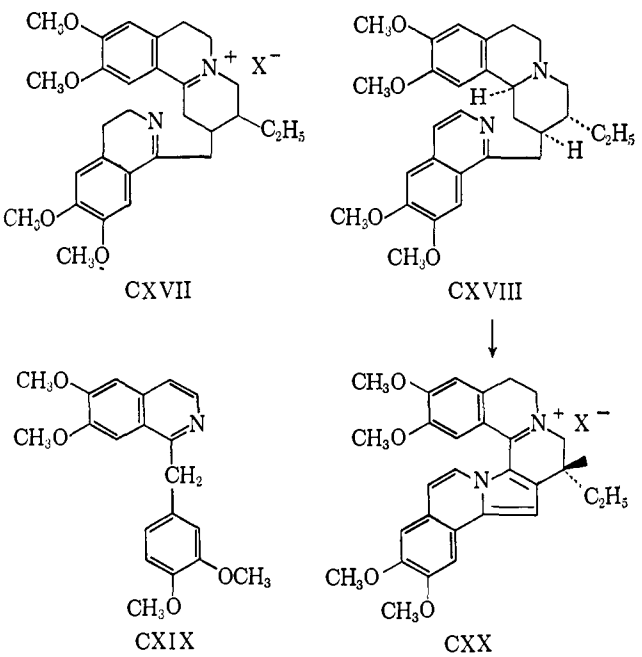
Figure 10.—Isoquinolines. Protopines: allocryptopine (CXXIa) in ethanol; cryptopine (CXXIb) in 2 *N* acid. Phthalideisoquinoline: narcotine (CXXII, R = CH_3) in ethanol. Protoberberines: berberine (CXXV) hydrochloride in ethanol; tetrahydroberberine (CXXIX) in ethanol.

2. *Psychotrine Group*

O-Methylpsychotrine (CXIVf) has maxima at 241, 290, 305, and 360 mμ (66, 256) (Figure 9). The 360-mμ maxima lies further towards the visible than the maximum of emetamine or papaverine (see below). The spectrum is consistent with the addition of a 3,4-dihydroisoquinoline and a tetrahydroisoquinoline system (256). Also tetradehydroemetine (CXVII) has maxima at 308 (log ε 4.17) and 358 mμ (4.17).

3. *Emetamine Group*

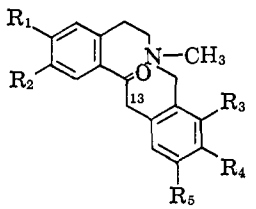
The alkaloid emetamine (CXVIII) is more highly unsaturated, with an isoquinoline ring system isolated from an aromatic ring. The spectrum should be approximately the summation of a 1-alkyl-6,7-dimethoxyisoquinoline and a veratrole chromophore. In fact, the spectrum of emetamine is practically identical with that of papaverine (CXIX) with maxima at 236, 283, 314, and 327 mμ (29).



Emetamine (CXVIII) readily dehydrogenates to the rubremetamine salts (CXX) with characteristic ultraviolet spectra (Figure 9).

F. PROTOPINES

The protopine bases are to be found mainly in the Papaveraceae (232). The ultraviolet spectra of the following are considered.



CXXI

a	Allocryptopine	$R_1 + \underset{H}{R_2} = CH_2O_2$, $R_3 = R_4 = OCH_3$, $R_5 =$
b	Cryptopine	$R_1 = R_2 = OCH_3$, $R_3 + R_4 = CH_2O_2$, $R_5 =$
c	Protopine	$R_1 + \underset{H}{R_2} = CH_2O_2$, $R_3 + R_4 = CH_2O_2$, $R_5 =$
d	Fagarine	$R_1 + \underset{OCH_3}{R_2} = CH_2O_2$, $R_3 = H$, $R_4 = R_5 =$

These bases show an absorption spectrum with one main band (286–293 mμ) and a shoulder at or near 240 mμ. It has been shown for cryptopine that bonding of the type $CH_3\ddot{N}\ldots CO$ strongly influences the carbonyl absorption frequency in the infrared spectrum (7), and this bonding can be expected to influence the ultraviolet spectral pattern of these bases (Figure 10).

In acid solution the absorption curve shows slightly lower extinction values, and the only marked change is in the accentuated lowering of the minimum near 260 mμ.

Mercuric acetate oxidations in conjunction with ultraviolet spectral studies are of some diagnostic value. Protopine, for example, yielded oxyprotopine,

a 13-keto derivative, and the ultraviolet spectrum in ethanol shows bands at 288 and 317 mμ (log ε 3.97 and 3.93) (226). See Table XV for ultraviolet data in these compounds.

TABLE XV

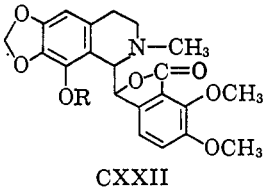
PROTOPINES

Compound	λ_{max}, mμ	Log ε	Solvent[a]	Ref.
Allocryptopine	237 sh, 288 (λ_{min} 258)	4.0, 3.8 (3.7)	E	278
Cryptopine	234, 286 (λ_{min} 222, 258)	4.02, 3.76 (3.94, 3.07)	$2NH^+$	255
Fargarine II	240 sh, 292	4.0, 3.9	E	278
Protopine	293	3.93	E	255

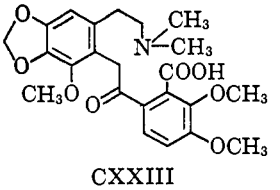
[a] E = ethanol (95%-absolute).

G. PHTHALIDEISOQUINOLINES

Narcotine (CXXII, R = CH_3) is a typical representative of this group and shows an ultraviolet spectrum with maxima at 209, 291, and 309–310 mμ (log ε 4.06, 3.60, and 3.69), a shoulder at *ca.* 235 mμ, and minima at 263 and 294 mμ (log ε 3.25 and 3.59) in ethanol (255) (Figure 10).



CXXII



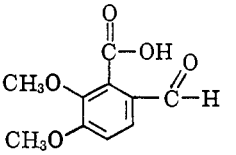
CXXIII

Narcotine hydrochloride is similar to the free base. A solution of the alkaloid narcotoline (CXXII, R = H) which has a free phenolic hydroxide goes yellow when heated with dilute alkali (260), and a study has been made of the spectrum with pH. A similar study has been made on narcotine (117).

The alkaloid narceine (CXXIII) has been included here because of its close structural relationship with the phthalideisoquinolines. In ethanol the ultraviolet spectrum has a single maximum at 270 mμ (log ε 3.98) and in dilute hydrochloric acid it shows two bands, one at 208 (log ε 4.76) and the other at 277 mμ (4.19) (227).

Opianic acid (CXXIV) is an important acid degradation product from some phthalideisoquinoline alkaloids, and the ultraviolet spectrum shows three maxima, 209, 229–231, and 282–289 mμ (log ε 4.18, 4.08, and 4.14).

For other spectral data, see Table XVI.



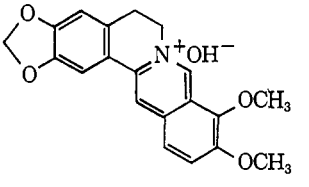
CXXIV

H. PROTOBERBERINE

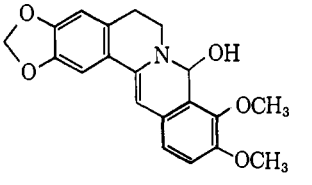
This group can be subdivided into the following types (Table XVII): (1) protoberberines, (2) tetrahydroprotoberberines, (3) oxyprotoberberine, and (4) dihydroprotoberberine.

1. Protoberberines

The yellow alkaloid berberine (CXXV) is typical of this group. Berberine hydrochloride shows a spectrum with three maxima, 267, 347, and 426 mμ (log ε 4.45, 4.42, and 3.75) (Figure 10), and the band at 426 mμ is



CXXV



CXXVI

in keeping with the fact that the alkaloid is yellow in the visible. In aqueous solution, the addition of sodium hydroxide up to a concentration of 0.25 *N* has no effect on the spectrum (308), but at higher concentrations a pink precipitate is formed which rapidly becomes orange because of the formation of oxyberberine (CXXVII, R = O) (145). In alcohol solution, however, even low concentrations of alkali change the spectrum, and at a concentration of 2×10^{-3} *N* or stronger, berberinol (CXXVI) is believed to have formed. Berberinol

TABLE XVI

PHTHALIDEISOQUINOLINES

Compound	λ_{max}, mμ	Log ε	Solvent[a]	Ref.
Narcotine	209, 291, 309–310 (λ_{min} 263, 296)	4.86, 3.60, 3.69 (3.24, 3.56)	E	255
Narcotine hydrochloride	211, 291, 313	4.76, 3.40, 3.54	W	255
Narcotine	320	3.7	B, pH 2–6	117
	290	3.5	B, pH 8–10	
	285	3.8	B, pH 12	
Narceine	270	3.98	E	255
Narceine hydrochloride	208, 277	4.76, 4.19	E	255
Opianic acid	209, 224–231, 282–289 (λ_{min} 225, 250)	4.18, 4.08, 4.14 (4.06, 3.41)	W	255

[a] See footnote in Table I for key to solvents.

TABLE XVII

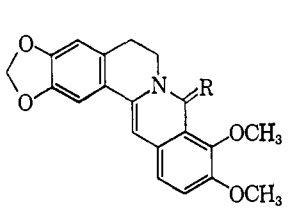
PROTOBERBERINE ALKALOIDS

Compound	λ_{max}, mμ	Log ε	Solvent[a]	Ref.
	1. Protoberberines			
Berberastine	228, 265, 344, 424 (λ_{min} 212, 250, 302.5, 377)	4.63, 4.41, 4.35, 3.77	W	252
Berberine hydrochloride	267, 347, 426 (λ_{min} 250, 305, 382)	4.45, 4.42, 3.75 (4.26, 3.8, 3.46)	E	308
Berberine iodide	226.5, 263, 344.5, 423	4.61, 4.41, 4.36, 3.73	W	252
	2. Tetrahydroprotoberberines			
Discreatamine	207, 228 sh, 285	4.79, 4.25, 3.77	E	302
Discretine	206, 228 sh, 282	4.78, 4.25, 3.77	E	302
Discretinine	204, 228 sh, 285	4.77, 4.25, 3.77	E	302
Stylopine (tetrahydrocoptisine)	240, 290, 355	4.0, 4.01, 1.40	E	22
Tetrahydroberberine	209, 230 sh, 284 (λ_{min} 252)	4.45, 4.07, 3.71 (2.76)	E	292
Xylopinine	206, 228 sh, 287	4.79, 4.25, 3.91	E	302
	3. Oxyprotoberberine			
Berlambine	223.5, 290, 340	4.72, 4.01, 4.46	E	89
	4. Dihydroprotoberberine			
Lambertine	285	4.45	E	89

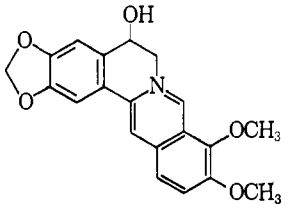
[a] E = ethanol (95%-absolute); W = water.

has λ_{max} 280 and 362 mμ, and in 0.25 *N* alcoholic potassium hydroxide, berberine shows maxima at 272 and 353 mμ which represent a 1:3 mixture of CXXV and CXXVI (308).

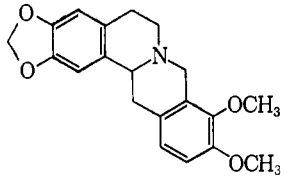
Berberastine (CXXVIII) has a spectrum with maxima at 228, 265, 344, and 424 mμ (λ_{min} 212, 250, 302.5, and 377 mμ) (252).



CXXVII



CXXVIII



CXXIX

2. *Tetrahydroprotoberberines*

Limited reduction of berberine yields tetrahydroberberine (CXXIX) which shows maxima at 209 and 284 mμ (log ε 4.45 and 3.71) and a shoulder at 230 mμ (log ε 4.07) (292). This spectrum (Figure 10) is characteristic for members of this group, and it is most likely that the band at 355 mμ (log ε 1.40), as recorded for *dl*-tetrahydrocoptisine (stylopine) (22), is due to traces of impurities.

3. *Oxyprotoberberine*

The only member so far known in this group is berlambine (CXXVII, R = O) isolated from the *Berberis* genus and is identical with oxyberberine. The ultraviolet spectrum shows three maxima, 223.5, 290, and 340 mμ (log ε 4.72, 4.01, and 4.46) (89).

4. *Dihydroprotoberberine*

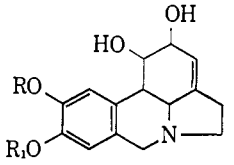
Lambertine (CXXVII, R = H_2) is the only representative in this group (89), and the spectrum in ethanol shows only a single band at 285 mμ (log ε 4.45).

XI. AMARYLLIDACEAE GROUP

The Amaryllidaceae alkaloids can be divided into seven main groups on the basis of their chemical structures and consideration of the ultraviolet spectra will be on this basis (Table XVIII).

A. PYRROLO[*de*]PHENANTHRIDINE DERIVATIVES

A member of this group, lycorine (CXXX, R + R_1 = CH_2) (Figure 11), shows an ultraviolet spectrum with a maximum at 279 mμ (log ε 3.7) and of some diagnostic significance is a shoulder at 237 mμ (log ε 3.5) which occurs in most of these alkaloids containing a methylenedioxy substituent on the phenyl ring (343).



CXXX

TABLE XVIII

AMARYLLIDACEAE ALKALOIDS

Compound	λ_{max}, mμ	Log ε	Solvent[a]	Ref.
A. Pyrrolo[*de*]phenanthridine derivatives				
1-Acetyllycorine	236, 293	3.59, 3.68	E	230
Caranine	233–236 sh, 292–296	3.47, 3.68	E	236
Falcatine	287	3.23	E	343
Galanthine	284	3.41	E	127
Lycorine	237 sh, 297 (λ_{min} 260)	3.5, 3.7 (2.61)	E	195
Methylpseudolycorine	285	3.58	E	127
	235, 283	3.89, 3.53	E, H^+ (0.01 *N*)	
Narcissidine	227 (inf), 284	3.96, 3.53	E	130
Pluviine	282	3.59	E	57
B. [2]Benzopyrano[3,4-*g*]indole Derivatives				
Albomaculine	224, 266, 295 sh	4.44, 4.03, 3.41	E	63
Clivonine	226, 268, 308	4.33, 3.77, 3.76	E	63
Desmethylhomolycorine	229, 269, 307	4.32, 3.88, 3.73	E	329
Hippeastrine	227, 268, 308	4.51, 3.86, 3.89	E	197
Homolycorine	225, 267, 305 (λ_{min} 253, 285)	4.18, 3.91, 3.69 (3.30, 3.56)	E	214
Krigeine	279, 287	3.06, 3.03	E	63
Krigenamine	280–285	3.14	E	146
Lycorenine	285 (λ_{min} 253)	3.51 (2.52)	E	214
Nevonine	228, 285, 310 sh	4.41, 3.85, 3.55	E	63
Nivaline	230, 269, 308	4.43, 3.75, 3.77	E	63
C. Dibenzofuran Derivatives				
Galanthamine	227, 288	3.98, 3.40	E	212
Narcissamine	287	3.38	E	127
D. [2]Benzopyrano[3,4-*c*]indole Derivatives				
Criwelline	240, 295	3.75, 3.68	E	128
Tazettine	242, 295	3.69, 3.65	E	341
E. 5,10b-Ethanophenanthridine Derivatives				
Buphanamine	285	3.18	?	281
Buphanidrine	287	3.29	?	281
Buphanisine	239, 295	3.50, 3.75	?	281
Buphanitine (haemanthine)	2.85	3.23	?	27
Crinamidine	288	3.19	E	230
Crinamine	234–240 sh, 297	3.53, 3.71	E	236
Crinidine (crinine)	240, 296	3.52, 3.72	E	236
Haemanthamine	296	3.73	E	129
Haemanthidine	241, 293	3.46, 3.62	E	197
6-Hydroxycrinamine (epihaemanthidine)	240, 294	3.54, 3.66	E	128
Nerbowdine	287	3.21	E	230
Powelline	288	3.23	E	340
Undulatine	288	3.20	E	334
F. N-Benzyl-N-(β-phenethylamine) Derivatives				
Belladine	278, 284 sh	3.69, 3.64	E	333
G. 11H-Dibenz[*b*,*e*]azepine Derivatives				
Coccinine	213, 244, 296	4.25, 3.58, 3.64	E	342
Manthidine	240, 294	3.62, 3.73	E	196
Manthine	243, 294	3.64, 3.71	E	342
Montanine	244, 297	3.65, 3.71	E	342

[a] E = ethanol (95%–absolute); H^+ = acid solution.

Methylpseudolycorine (CXXX, R = R_1 = CH_3), which has λ_{max} 285 mμ (log ε 3.58), shows two maxima in dilute acid solution, λ_{max} 235 and 283 (log ε 3.39 and 3.53).

B. [2]BENZOPYRANO[3,4-*g*]INDOLE DERIVATIVES

This group can be subdivided into alkaloids containing a benzylic hemiacetal function and those alkaloids with an aromatic δ-lactone system. Lycorenine

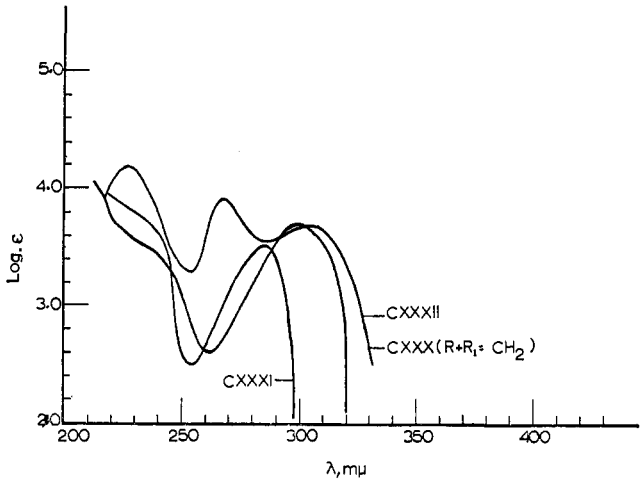
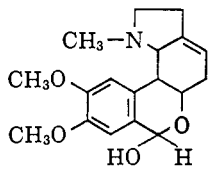
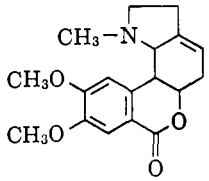


Figure 11.—Amaryllidaceae: lycorine (CXXX, R + R_1 = CH_2) in ethanol; lycorenine (CXXXI) in ethanol; homolycorine (CXXXII) in ethanol.

(CXXXI) (Figure 11) which shows a single maximum at 285 mμ (log ε 3.51) is a typical example of the former group, and homolycorenine (CXXXII) (Figure 11), showing three maxima at 225, 267, and 305 mμ (log ε 4.18, 3.91, and 3.69), exemplifies the latter group.



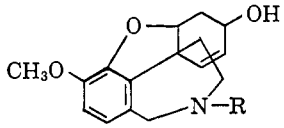
CXXXI



CXXXII

C. DIBENZOFURAN DERIVATIVES

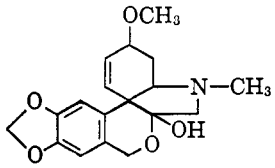
Galanthamine (CXXXIII, R = CH_3) and narcissamine (CXXXIII, R = H) are examples in this group. Both show a single maximum at 287–288 mμ owing to the aromatic ring. Galanthamine is characterized by the fact that it shows a flat maximum with a slight minimum between 283 and 288 mμ (212).



CXXXIII

D. [2]BENZOPYRANO[3,4-*c*]INDOLE DERIVATIVES

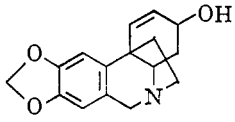
Tazettine, isotazettine, and criwelline (CXXXIV) are three members in this group. Tazettine shows an ultraviolet spectrum with two maxima at 242 and 295 mμ (log ε 3.69 and 3.65) and a minimum at 262 mμ (log ε 2.62).



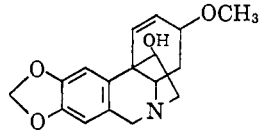
CXXXIV

E. 5,10*b*-ETHANOPHENANTHRIDINE DERIVATIVES

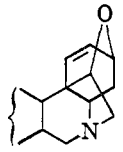
This group is also called the crinidine (CXXXV) type and although all the members contain methylenedioxy substituents, only some show a band or shoulder at or near 240 mμ. The band between 285 and 297 mμ is due to the aromatic ring.



CXXXV



CXXXVI

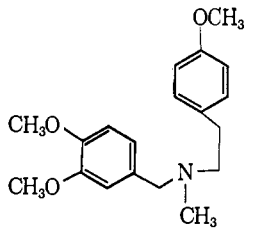


CXXXVIA

Haemanthamine (CXXXVI), λ_{max} 296 mμ (log ε 3.73), is converted to the demethoxy ether (CXXXVIA) in dilute acid and shows an unchanged ultraviolet spectrum (129).

F. N-BENZYL-N-(β-PHENETHYLAMINE) DERIVATIVES

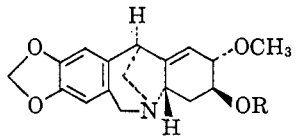
Belladine (CXXXVII) is the only known member in this group, and this alkaloid, which is a key product in the biogenesis of some other Amaryllidaceae alkaloids, shows an ultraviolet spectrum with λ_{max} 284 mμ (log ε 3.64) and a shoulder at 278 mμ (log ε 3.69).

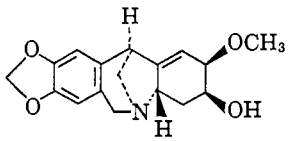


CXXXVII

G. 11H-DIBENZ[*b*,*e*]AZEPINE DERIVATIVES

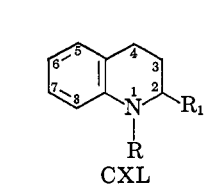
Montanine (CXXXVIII, R = H), manthine (CXXXVIII, R = CH_3), and coccinine (CXXXIX) are known members of this group. Manthidine and brunvigine are also believed to be of a similar structural type (196). Their ultraviolet spectra have two maxima, at 240–244 and 294–297 mμ. The ultraviolet spectra of dehydro products from these alkaloids represent two isolated benzenoid chromophores and not a biphenyl conjugation as is obtained from most of the previously known Amaryllidaceae ring systems and was important evidence in establishing this new structural type.

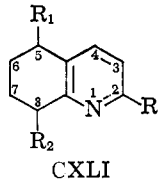

CXXXVIII

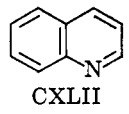

CXXXIX

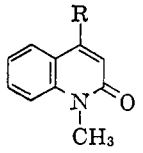
XII. QUINOLINE GROUP

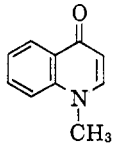
This group of alkaloids, found largely in the Rubiacea and Rutacea, range in structural complexity from the simple tetrahydroquinolines to the more complex furoquinolines and cinchona alkaloids. The group may be classified into the following structural types: (A) tetrahydroquinolines (CXL, CXLI); (B) quinolines (CXLII); (C) 2-quinolones (CXLIII); (D) 4-quinolones (CXLIV) including the dihydrofuro-4-quinolones (CXLV) and the pyrano-4-quinolones (CXLVI); (E) furoquinolines (CXLVII)[5] and the related dihydrofuroquinolines (CXLVIII) and dimethylpyranofuroquinolines (CXLIX or CL)[6]; (F) dehydropyrano-2-quinolones (CLI).[7] The isofuroquinolones (CLII), isomeric transformation products of the furoquinolines (CXLVII), and the furo-2-quinolone (CLIII), a transformation product of the quinoline (CLIV), are also worthy of mention. Several of these groups show similarities in their ultraviolet spectra.

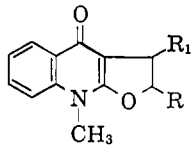

CXL

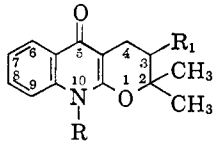

CXLI

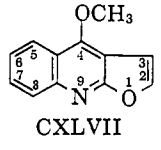

CXLII

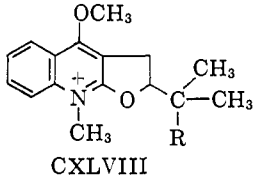

CXLIII

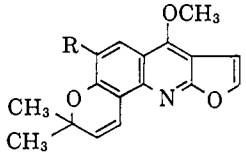

CXLIV

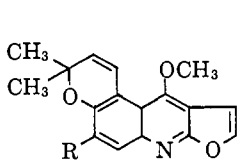

CXLV

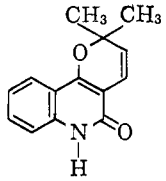

CXLVI

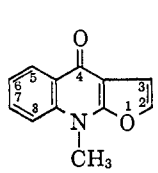

CXLVII

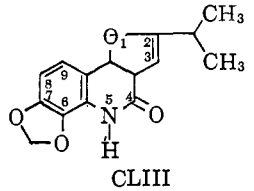

CXLVIII

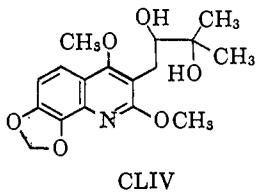

CXLIX


CL


CLI


CLII


CLIII


CLIV

The ultraviolet spectral properties of these alkaloids have been very useful in structural elucidation, and spectral data are summarized in Table XIX, which is presented according to the classification above. Usually a reference compound is given for each group before the listed alkaloids and examples of the spectra are shown in Figures 12–18.

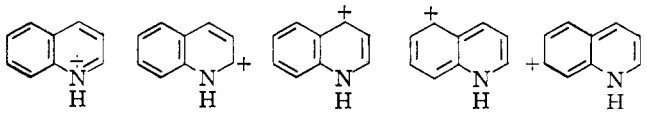
A. TETRAHYDROQUINOLINES

The tetrahydroquinolines fall into two classes depending on whether the aromatic or the heterocyclic ring is saturated. 1,2,3,4-Tetrahydroquinolines (CXL) show two maxima at 248 (log ϵ 3.86) and 303 mμ (3.48) not unlike substituted anilines (279). Cuspareine, the only example in this group (CXL, R = CH_3; R_1 = $-CH_2CH_2[3,4-(CH_3O)_2Ph]$), might be expected to show a similar spectrum with somewhat higher intensity because of the presence of the additional nonconjugated benzene ring.

5,6,7,8-Tetrahydroquinoline shows two maxima at 215 (log ϵ 3.55) and 270 mμ (log ϵ 3.65) (155). Fabianine (CXLI) (R = R_1 = CH_3; R_2 = $-C(CH_3)_2OH$) shows similar maxima (121).

B. QUINOLINES

The spectra of the alkaloids in this group depend to a large extent on the substitution of the quinoline ring. Quinoline itself is characterized by three main regions of absorption: the first at 227 mμ (log ϵ 4.56), the second a broad band at 280 mμ (log ϵ 3.56) with a side peak at 310 mμ (log ϵ 3.43), and the third at 314 mμ (log ϵ 3.47) (Figure 12). The latter two regions of absorption become one band on acidification, the maximum now being at 312 mμ (log ϵ 3.84) (124). This bathochromic shift on acidification can be attributed to the large number of resonance structure (CLV–CLIX) which contribute to the stability of the protonated form. In nonpolar solvents the spectrum shows additional fine structures (140).


CLV CLVI CLVII CLVIII CLIX

(5) The numbering of ring is as in ref. 6. CXLVII is a furo[2,3-*b*]quinoline and its angular isomer is [3,2-*c*].

(6) Unpublished n.m.r. data of Drs. S. M. Goodwin and J. R. Price support structure CL (see ref. 269).

(7) CLI is a pyrano[3,2-*c*]quinoline and its linear isomer is [2,3-*b*].

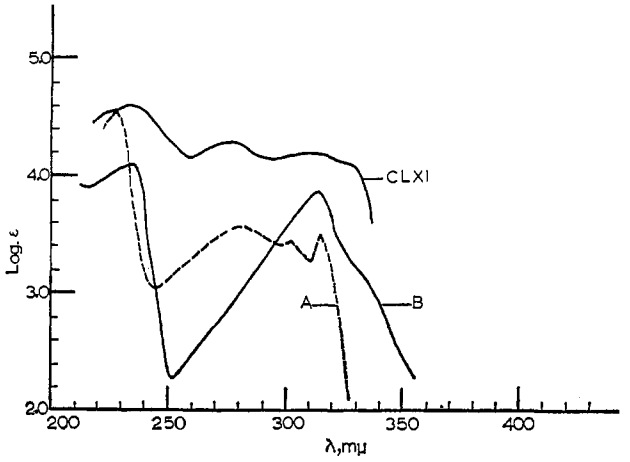


Figure 12.—Quinoline group: graveolinine (CLXI) in ethanol; (A) quinoline (CXLII) in ethanol; (B) quinoline in 0.01 *N* hydrochloric acid.

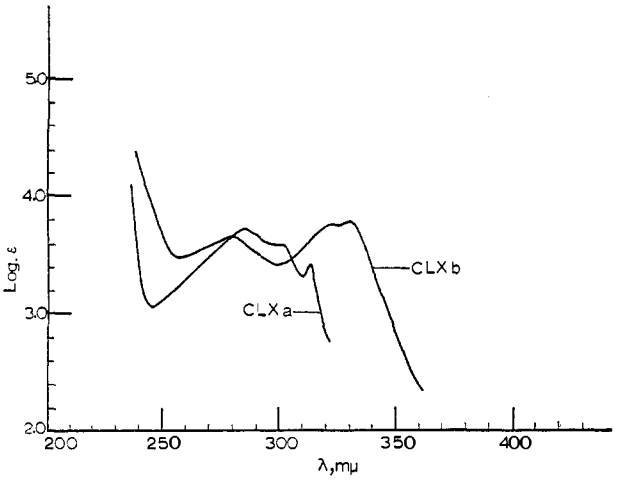
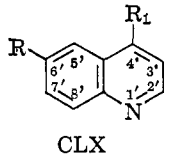


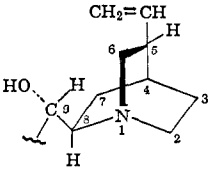
Figure 13.—Quinoline group: cinchonine (CLXa) in water at pH 8; quinine (CLXb) in water at pH 7.5.

Substituents on the quinoline ring may be non-conjugative (OH, OCH_3, alkyl) as in the cinchona series, or conjugative (*e.g.*, phenyl) as illustrated by some of the Angostura alkaloids.

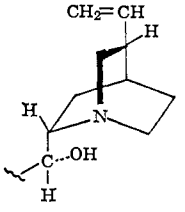
The spectra of the cinchona group of alkaloids fall into two categories, the cinchonine (CLXa) series and the quinine (CLXb) series. The cinchonine series

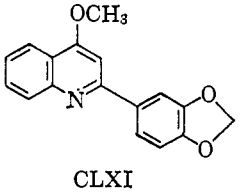


(a), R = H, R_1 =



(b), R = OCH_3, R_1 =





CLXI

(cinchonine, cinchonidine, dihydrocinchonine, dihydrocinchonidine, etc.) have spectra which are quite similar to quinoline with a maximum at 280 mμ (log ε 3.7) and two smaller maxima at *ca.* 300 (log ε ∽3.6) and 315 mμ (log ε ∽3.4) (Figure 13). The quinine series (quinine, quinidine, epiquinine, epiquinidine, dihydroquinine, etc.) show maxima at *ca.* 280 mμ (log ε ∽3.7) and a broad bifurcated maxima at 320–335 mμ (log ε ∽3.8) (Figure 13). These differences are attributed to changes in electronic configuration in the quinoline ring. achieved either by introduction of an auxochrome, or by variation in the average planarity of the molecules as controlled by epimerization at C_8 and C_9 (317). The differences have been used to characterize the two series and have been used for quantitative measurements. The effect of pH changes on the spectra have also been studied. In the quinine series, increasing acidity (to pH 1) causes the disappearance of the 280-mμ band, and the 320–335-mμ bands are split into two peaks at 315 and 350 mμ. In the cinchonine series, the addition of acid (to pH 1) causes the disappearance of the 280-mμ band, and the two smaller maxima are shifted hyperchromically to a broad partly bifurcated maximum at 305–315 mμ (Figure 14).

Quinoline alkaloids of the Rutacea show spectra similar to quininoline, the positions of the maxima depending on the type of substituent. 4-Methoxy-2-phenylquinoline shows two maxima at 254 and 295 mμ, the latter being shifted to 316 mμ on acidification. Both these bands are at lower wave lengths than in

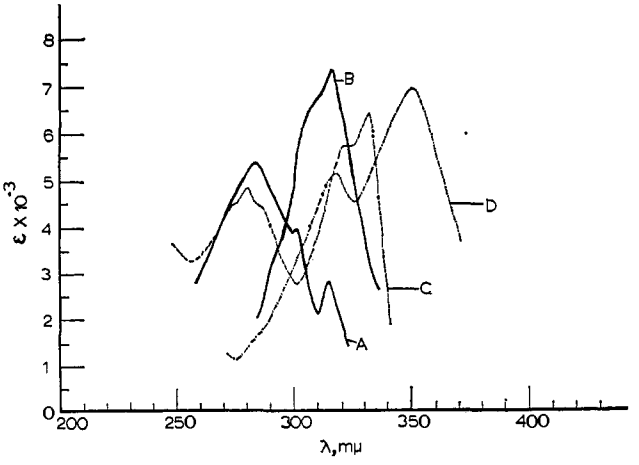


Figure 14.—Quinoline group: (A) cinchonine (CLXa) in water at pH 8; (B) cinchonine in acid at pH 1; (C) quinine (CLXb) in water at pH 7.5 and 9.5; (D) quinine in acid at pH 1.

TABLE XIX

QUINOLINE GROUP

Compound	λ_{max}, mμ	Log ε	λ_{min}, mμ	Log ε	Solvent[a]	Ref.
Tetrahydroquinolines						
1,2,3,4-Tetrahydroquinoline	248, 303	3.86, 3.48	228, 279	3.51, 3.12	E	304
5,6,7,8-Tetrahydroquinoline	215, 270	3.55, 3.65	...	...	E	155
Fabianine	213, 273	3.9, 3.8	...	...	E	121
Quinolines						
Quinoline	227, 278, 301, 314	4.56, 3.56, 3.43, 3.47	243, 296, 310	3.02, 3.42, 3.27	E	
	234, 312, 327 sh	4.10, 3.84, 3.25	213, 250	3.90, 2.28	H^+ (0.01 *N*)	124
Cinchonidine	283, 300, 313	3.73, 3.60, 3.43	299, 308	3.59, 3.35	pH 6.00,[b] W	317
Cinchonine	283, 300, 314	3.73, 3.59, 3.42	298, 309	3.59, 3.32	pH 8.0,[b] W	317
Dihydrocinchonidine	282, 300, 314	3.57, 3.42, 3.26	299, 309	3.41, 3.16	pH 6,[b] W	317
Dihydrocinchonine	282, 300, 314	3.71, 3.58, 3.44	299, 309	3.57, 3.30	pH 8.0,[b] W	317
Dihydrodictamnine	229 sh, 238 sh, 253 sh, 263, 272, 283 sh, 298 sh, 308, 320	4.67, 4.53, 3.60, 3.75, 3.83, 3.75, 3.34, 3.58, 3.65	...	...	E	98
Dihydroquinidine	272 sh, 279, 284 sh, 322 sh, 332	3.59, 3.63, 3.58, 3.68, 3.72	254, 300	3.42, 3.37	pH 6.0,[b] W	317
Dihydroquinine	274 sh, 279, 284 sh, 322 sh, 332	3.56, 3.59, 3.54, 3.65, 3.69	253, 300	3.39, 3.34	pH 6.0,[b] W	317
Epiquinidine	281, 286 sh, 325 sh, 333	3.56, 3.53, 3.66, 3.68	302	3.35	pH 8.2,[b] W	317
Epiquinine	275 sh, 280, 287 sh, 325 sh, 332	3.51, 3.53, 3.50, 3.64, 3.67	258, 301	3.38, 3.32	pH 8.2,[b] W	317
Graveolinine [2-(3′,4′-methylenedioxyphenyl)-4-methoxyquinoline]	224 sh, 234, 274, 311, 323 sh	4.55, 4.61, 4.28, 4.17, 4.11	258, 291	4.13, 4.13	E	86, 160
4-Methoxy-2-phenylquinoline	254, 294	4.64, 4.01	230, 276	4.32, 3.97	E	158
	231, 254, 316	4.37, 4.51, 4.16	239, 283	4.31, 3.90	E + H^+	158
Quinidine	273 sh, 279, 286 sh, 322, 331	3.58, 3.61, 3.57, 3.71, 3.75	256, 300, 323	3.43, 3.37, 3.70	pH 8.0,[b] W	317
Quinine	273 sh, 280, 284 sh, 320, 331	3.61, 3.68, 3.59, 3.76, 3.80	256, 300, 324	3.51, 3.43, 3.76	pH 7.5,[b] W	317
2-Quinolones						
3,4-Cyclohexane-2-quinolone (spectrum identical with that of 2-quinolone)	269, 277, 321, 336	3.83, 3.76, 3.99, 3.70	256, 275, 289, 333	3.70, 3.75, 3.28, 3.69	E	124, 347
Casimiroin	226, 236, 252, 260, 300	4.50, 4.45, 4.35, 4.34, 3.84	...	...	E	211
Eduleine	250, 257, 314, 323	4.54, 4.52, 4.14, 4.15	275	3.35	E	202
Hydroxylunacridine	239, 257, 284, 293, 332, 345 sh	4.39, 4.39, 3.93, 3.90, 3.55, 3.41	224, 246, 275, 291, 310	4.32, 4.32, 3.88, 3.90, 3.37	E	160
Hydroxylunidine	228, 237 sh, 260, 267, 318, 330 sh	4.43, 4.36, 4.33, 4.37, 3.94, 3.83	249, 279	4.12, 3.53	E	160
Lunacridine	239, 257, 285, 294, 333	4.38, 4.41, 3.94, 3.91, 3.55	224, 246, 275, 291, 310	4.31, 4.31, 3.89, 3.90, 3.36	E	90, 156
Lunidine	216 sh, 226, 236 sh, 259 sh, 266, 317, 331 sh	4.32, 4.42, 4.35, 4.31, 4.35, 3.93, 3.81	248, 279	...	E	288
Lunidonine	216 sh, 226, 236 sh, 259 sh, 266, 312, 331 sh	4.33, 4.41, 4.37, 4.30, 4.35, 3.93, 3.78	...	...	E	288
1-Methyl-3-(γ-hydroxy)-propyl-4,8-dimethoxy-2-quinolone	238, 257, 283, 291 sh, 331	4.37, 4.39, 3.90, 3.87, 3.53 ε-values[c] 23,700, 24,800, 8000, 7400, 3400	...	...	M	274

TABLE XIX (*Continued*)

Compound	$\lambda_{max.}$ mμ	Log ε	$\lambda_{min.}$ mμ	Log ε	Solvent[a]	Ref.
	238, 256, 283, 291 sh, 331	4.36, 4.39, 3.89, 3.86, 3.53 ε-values[c] 23,100, 24,800, 7700, 7200, 3400			H^+ (0.2 N), M	274
	242, 256, 271, 282, 292, 335	4.48, 4.33, 3.83, 3.88, 3.84, 3.57 ε-values[c] 30,200, 21,200, 6700, 7600, 6900, 3700			H	274
Pilokeanine	229, 238, 254, 262, 272, 283, 295 sh, 307, 321	4.57, 4.43, 3.50, 3.65, 3.73, 3.65, 3.24, 3.49, 3.55	237, 249, 267, 278, 292, 314	4.42, 3.43, 3.64, 3.59, 3.23, 3.38	E	338
	216, 236, 240, 292, 303, 315	4.39, 4.40, 4.33, 3.89, 3.86, 3.69	226, 253, 312	4.23, 3.24, 3.68	E, H^+ (0.01 N)	338
			4-Quinolones			
2,3-Cyclopentano-4-quinolone (spectrum identical with 4-quinolone)	238, 318, 331	4.48, 4.09, 4.13	222, 261, 323	4.15, 3.00, 3.99	E	124, 347
Echinopsine	233, 239, 281, 291, 326, 340	4.24, 4.30, 3.36, 3.47, 4.14, 4.17	...	...	E	121
Eduleine	250, 257, 314, 323	4.54, 4.52, 4.14, 4.15	...	...	E	202
Lunamarine	228, 246, 250, 259, 317, 324 sh	4.50, 4.48, 4.48, 4.51, 4.28, 4.27	239, 248, 255, 287	4.46, 4.48, 4.44, 3.83	E	160
			Dihydrofuro-4-quinolones			
Balfourodine	219, 241, 299, 312, 326	4.34, 4.64, 4.03, 4.05, 3.98	...	...	M	273
	214, 257, 299, 315 sh	4.45, 4.58, 3.94, 3.63	...	...	M, H^+ (0.1 N)	
Hydroxylunacrine[d]					E	156
Hydroxylunine	220, 246, 268 sh, 320, 330	...	224, 282, 320	...	E	
	223, 260, 340	...	233, 277	...	E, H^+ (0.1 N)	160
Ifflaimine	215, 236, 251 sh, 298 sh, 309, 320	4.51, 4.39, 4.18, 3.91, 4.05, 4.01	265	3.30	E	
	216, 235, 294, 315 sh	4.52, 4.59, 4.10, 3.83	...	...	M, H^+ (0.2 N)	59
	236 sh, 251, 261, 275, 288 sh, 305, 315, 326	4.25, 4.10, 4.19, 3.52, 3.48, 3.81, 3.96, 3.87	...	...	Cy	
Lunacrine	220, 242, 300, 313, 326	4.34, 4.61, 4.00, 4.01, 3.99	225, 269, 306, 319	4.32, 3.45, 3.95, 3.93	E	156, 157
	216, 253 sh, 257, 300, 320 sh	4.54, 4.57, 4.59, 3.89, 3.58	234, 271	4.21, 3.62	E, H^+ (0.1 N)	156
Lunine	222, 247, 268 sh, 314, 325	4.31, 4.60, 3.97, 4.02, 4.01	228, 280, 319	4.28, 3.46, 4.00	E	
	257, 332	4.61, 3.86	233, 275	3.97, 3.21	E, H^+ (0.1 N)	157
			Pyrano-4-quinolones			
Khaplofoline	234, 310, 322	4.46, 3.98, 3.92	...	...	?	126
Isobalfourdine	216, 242, 298, 320, 330	4.24, 4.67, 4.86, 4.02, 3.95 ε-values[c] 17,500, 46,600, 7200, 10,400, 8900	...	...	M	274
	215, 253, 304, 326 sh	4.46, 4.65, 3.87, 3.62	...	...	M, H^+ (0.2 N)	274

TABLE XIX (*Continued*)

Compound	$\lambda_{max.}$ mμ	Log ε	$\lambda_{min.}$ mμ	Log ε	Solvent[a]	Ref.
		ε-values[c] 28,600, 44,200, 7400, 4200				
	230, 240 sh, 290, 319, 330	4.43, 4.37, 3.76, 3.97, 3.91 ε-values[c] 26,800, 23,700, 5800, 9400, 8200	...	...	H	274
			Furoquinolines			
Evolatine	243, 277 sh, 306, 318, 333	4.6, 3.35, 4.08, 4.11, 3.94	262, 312, 327	3.05, 4.01, 3.90	E	148
Evolitrine	246, 256 sh, 290 sh, 300 sh, 308, 319, 333	4.81, 4.28, 3.73, 3.88, 3.97, 3.96, 3.87	...	...	E	97
Evoxine	250, 304, 318, 336, 344 sh	4.9, 3.78, 3.86, 3.85, 3.75	277, 325	2.90, 3.84	E	118
Flindersiamine	212, 244, 299 sh, 310, 320, 333 sh	4.18, 4.84, 3.92, 4.06, 4.04, 3.88	...	...	M	274
	218, 253, 288	4.33, 4.72, 4.17	...	...	M, H^+ (0.2 *N*)	274
Kokusaginine	243, 273 sh, 307, 317, 333	4.60, 3.37, 4.02, 4.07, 3.90	262, 314, 327	3.03, 4.00, 3.96	E	148
	246, 352, 323, 334	4.17, 4.23, 3.64, 3.53	263, 315	2.71, 3.60	E	338
Isokokusagine	243 sh, 254, 273 sh, 304 sh, 339, 345 sh	4.21, 4.39, 4.19, 3.54, 3.98, 3.95	292	3.30	E	247
Maculine	245, 301 sh, 306, 314, 340	4.71, 4.16, 4.34, 4.28, 4.18	272, 316, 335	3.72, 4.25, 4.14	E	70
Maculosidine	211, 246, 284 sh, 294, 306, 338, 351	4.29, 4.85, 3.72, 3.86, 3.88, 3.76, 3.69	272, 300, 318, 346	3.15, 3.56, 3.25, 3.62	M	70, 274
	313, 254, 306, 317, 353	4.38, 4.78, 3.76, 3.84, 3.77	...	...	M, H^+ (0.2 *N*)	70
Maculosine	252, 295, 310, 323, 340	4.42, 4.05, 4.16, 4.15, 4.06	255, 303, 316, 335	3.06, 4.0, 4.11, 3.97	E	265
6-Methoxydictamnine	249, 261, 284 sh, 296, 307, 333, 350	6.10, 4.91, 4.81, 4.99, 5.04, 4.75, 4.68	220, 267, 324, 342	5.85, 4.62, 4.68, 4.63	E	338
6-Methoxyisodictamnine	217, 243, 255, 265, 290, 302, 329, 344, 361	3.91, 4.11, 4.03, 4.15, 3.19, 3.07, 3.38, 3.64, 3.66	225, 250, 260, 310, 350	3.86, 3.94, 3.99, 2.88, 3.53	E	338
Skimmiamine	250, 300 sh, 320, 336, 344 sh	4.9, 3.50, 3.86, 3.85, 3.75	277, 325	2.9, 3.84	E	70
			Dihydrofuroquinoline Salts			
Lunasine perchlorate	254, 303, 330 sh	4.56, 3.80, 3.46	232, 273	3.93, 3.43	E	156
O-Methylbalfourodinium perchlorate	215, 254, 301, 324 sh	4.49, 4.56, 3.88, 3.57	...	...	E	273
			Dihydrofuroquinolines			
Dubinidine	230, 274, 283, 309, 322	5.05, 4.33, 4.25, 4.07, 4.08	225, 251, 278, 296, 314	5.01, 4.09, 4.19, 3.8, 3.98	?	46
Dubinine	228, 230 sh, 274, 284, 303	5.27, 5.06, 4.33, 4.29, 4.17	251, 278, 295	4.09, 4.22, 4.08	?	46
			Dehydropyrano-2-quinolones and Angular Furoquinolones			
Flindersine	235 sh, 314 sh, 333, 350, 365	4.42, 3.58, 4.00, 4.10, 3.93	278, 338, 360	2.91, 4.97, 3.90	E	71
Orixidine	243, 259, 268, 307, 321, 336	4.40, 4.42, 4.46, 3.95, 4.01, 4.12	252, 263, 279, 315, 328	4.35, 4.39, 3.65, 3.91, 3.94	E	247

TABLE XIX (*Continued*)

Compound	λ_{max}, mμ	Log ε	λ_{min}, mμ	Log ε	Solvent[a]	Ref.
Orixidinine	227, 235 sh, 248, 265 sh, 314, 322, 328	4.49, 4.46, 4.41, 4.01, 3.97, 3.91, 3.95	243, 276, 318, 324	4.35, 3.54, 3.89, 3.88	E	247
			Dehydropyranofuroquinolines			
Acronidine	222, 253, 274 sh, 323 sh, 335, 384 sh, 361 sh	4.29, 4.68, 3.98, 4.07, 4.17, 4.01, 3.78	213, 227, 291	4.27, 4.26, 3.31	E	269
Isoacronidine	264, 311–316 sh, 323, 350 sh, 363, 380	4.53, 3.79, 3.84, 3.82, 4.01, 3.97	230, 300, 336, 372	4.2, 3.68, 3.62, 3.90	E	269
Medicosmine	253, 277 sh, 303 sh, 313, 327, 366, 381	4.79, 3.83, 3.73, 3.94, 4.02, 3.84, 3.84	226, 290, 318, 339, 375	4.16, 3.53, 3.90, 3.61, 382	E	269
Isomedicosmine	209, 254, 278 sh, 319–324 sh, 362, 375, 391	4.42, 4.57, 4.05, 3.22, 3.84, 4.10, 4.12	235, 330, 385	4.12, 3.10, 3.98	E	269

[a] See footnote in Table I for key to solvents. [b] Spectra also recorded at other pH values. [c] ε-Values plotted to illustrate solvent effects. [d] Identical with lunacrine (see below).

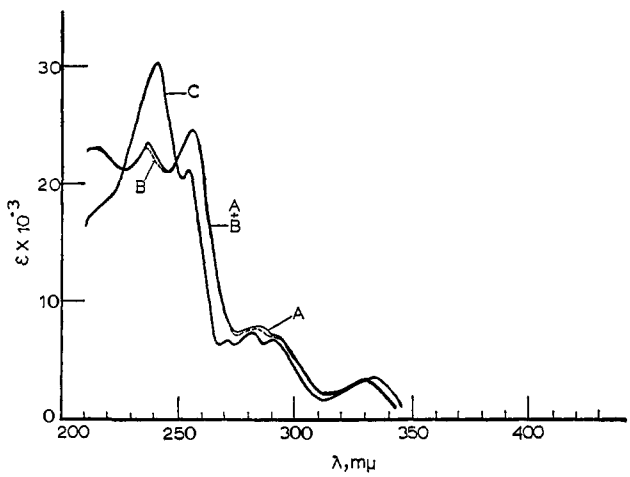


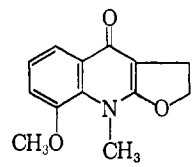
Figure 15.—Quinoline group: (A) 2-quinolones (CXLIII, R = OCH_3; $—CH_2CH_2CH_2OH$ at 2-position) in methanol; (B) in methanolic 0.2 *N* hydrochloric acid; (C) in hexane.

quinoline, but show higher log ε values. The spectrum of graveoline (CLXI) is similar (Figure 12).

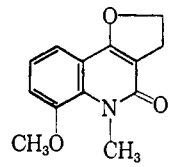
C. 2-QUINOLONES

The 2-quinolones are characterized by three main regions of absorption at *ca.* 230–240 (log ε ~4.4), 260–285 (~4.1), and 315–335 mμ (~3.8), the peaks often being bifurcated. The 2-quinolones can be distinguished from the 4-quinolones on the basis of a careful examination of their spectra. The 270–285-mμ band in the 2-quinolones is usually absent in the 4-quinolones or present only as a shoulder (69, 172), though the presence of several other oxygen functions in the molecule may diminish the significance of the comparison. The spectra of the 2-quinoles are essentially unchanged on the addition of acid or alkali (in contrast to the 4-quinolones).

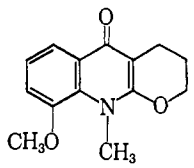
Another useful method for distinguishing between 2- and 4-quinolones is the difference in the spectra in *n*-hexane as opposed to methanol (274). In changing from methanol to hexane, the spectra of 2-quinolones are hardly changed at long wave lengths, but at shorter wave lengths there is a coalescence of bands to give one main band of high intensity at about 240 mμ (ε ~ 40,000) (Figure 15). In the case of the 4-quinolones, the long wave length band is not greatly changed, but



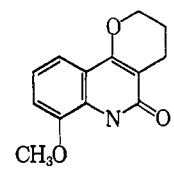
CLXII



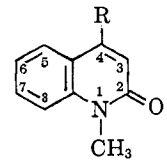
CLXIII



CLXIV



CLXV



CXLIII (R = OCH_3)

		3	7 8
a	Casimiroin		$-OCH_2O-$
b	Hydroxylunacridine	$CH_2CH(OH)C(OH)(CH_3)_2$	OCH_3
c	Hydroxylunidine	$CH_2CH(OH)C(OH)(CH_3)_2$	$-OCH_2O-$
d	Lunacridine	$CH_2CH(OH)CH(CH_3)_2$	OCH_3
e	Lunidine	$CH_2CH(OH)CH(CH_3)_2$	$-OCH_2O-$
f	Lunidonine	$CH_2C(O)CH(CH_3)_2$	$-OCH_2O-$
g	1-Methyl-3-(γ-hydroxy)propyl-4,8-dimethoxy-2-quinolone	$CH_2CH_2CH_2OH$	OCH_3

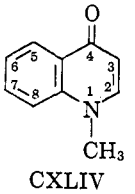
the short wave length band in addition to being hypochromically shifted (by about 15 mμ) is also split into several unresolved maxima of lowered intensity at about 225 mμ (ε ~26,000) (*cf.* isobalfourodine) (CXLVI, R = CH_3; R_1 = OH) and Table XIX (Figure 16). The method has also been used to distinguish between the linear and angular dihydrofuro- and pyranoquinolones of the types CLXII, CLXIII, CLXIV, and CLXV (274).

Examples of the 2-quinolone type alkaloids CXLIIIa–g are listed in Table XIX (see Figure 17).

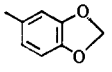
D. 4-QUINOLONES

The 4-quinolone group can be subdivided into the simple 4-quinolones (CXLIV), the dihydrofuro-4-quinolones (CXLV), and the pyrano-4-quinolones (CXLV). The spectra of these three types are quite similar and consist of two principal bands in the region 230–260 (log ε ~4.4) and 300–330 mμ (~3.8), the latter band often being split in alcoholic solutions. Another band is sometimes observed at *ca.* 215–220 mμ (log ε ~4.5). These bands are often broad and complex depending on the type of substitution, particularly if the substituents are aromatic. The 300–330-mμ band in 4-quinolones is shifted hyperchromically to a single maximum at *ca.* 310 mμ in normal acid solution (156, 160, 274) though it had been found previously (124) that in more dilute acid solution (0.01 *N*) no such change occurred. The 230–260-mμ band is shifted bathochromically on acidification. The pyrano-4-quinolone system has recently been shown to be present in alkaloids from *Hoplophyllum foliosum* species (126). The spectra of a number of 4-quinolone derivatives have been discussed from the molecular orbital point of view (69). The solvent effects discussed above under the 2-quinolones are illustrated with 1-methyl-3-(γ-hydroxy)propyl-4,8-dimethoxy-2-quinolone (a 2-quinolone) and isobalfouradine (CXLVIb) (a 4-quinolone) in Figure 16.

Examples of the 4-quinolones (CXLIV), dihydrofuro-4-quinolones (CXLV), and the pyrano-4-quinolones (CXLVI) are shown (see also Figure 17).



CXLIV

		2	3	7	8
a	Echinopsine	...	...	...	...
b	Eduleine	C_6H_5	...	OCH_3	...
c	Lunamarine		...	OCH_3	...
d	Pilokeanine[a]	. .	$CH_2CH(OH)CH(CH_3)_2$	...	OCH_3

[a] Tentative structure.

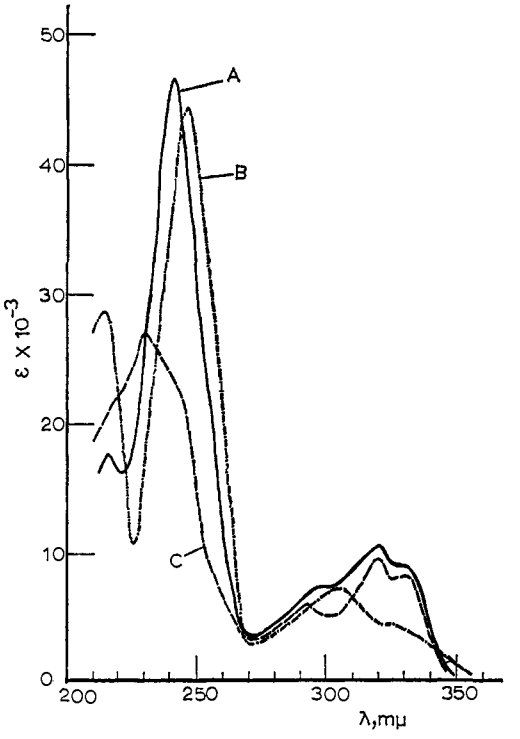
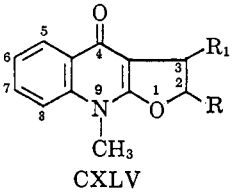


Figure 16.—Quinoline group. 4-Quinolones [isobalfourodine (CXLVI, R = CH_3; R = OH)]: (A) in methanol; (B) in methanolic 0.2 *N* hydrochloric acid; (C) in hexane.



CXLV

		R	R_1	7	8
a	Balfourodine	$-C(OH)(CH_3)_2$	H	...	OCH_3
b	Hydroxylunacrine	$-C(OH)(CH_3)_2$	H	...	OCH_3
c	Hydroxylunine	$-C(OH)(CH_3)_2$	H	$-OCH_2O-$	
d	Ifflaimine	CH_3	CH_3	...	...
e	Lunacrine	$CH(CH_3)_2$	H	...	OCH_3
f	Lunine	$CH(CH_3)_2$	H	$-OCH_2O-$	

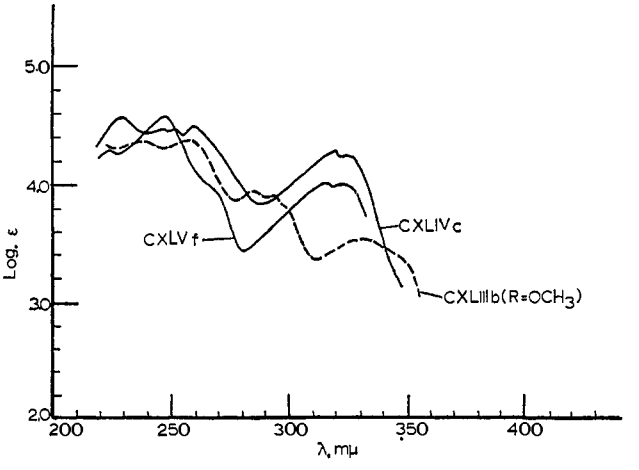
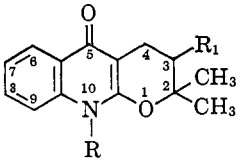


Figure 17.—Quinoline group: lunamarine (CXLIVc) in ethanol; lunine (CXLVf) in ethanol; hydroxylunacridine (CXLIIIb, R = OCH_3) in ethanol.

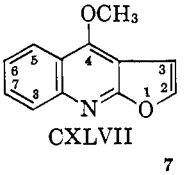


CXLVI

a Khaplofoline R = R_1 = H
b Isobalfourodine R = CH_3; R_1 = OH

E. FUROQUINOLINES

The furoquinolines, which are related to dictamnine (CXLVII), have a double bond conjugated with the quinoline ring and absorb at longer wave lengths than the simple quinolines. The spectra of the furoquinolines show two maxima at *ca.* 245 mμ (log ε ~4.7) and a very broad complex band in the region 290–330 mμ (log ε ~3.8). On heating, the salts of 4-methoxyfuroquinolines are converted to the iso series (OCH_3 → N–CH_3). This is a useful rearrangement as the 4-quinolone system now present shows band at *ca.* 260 mμ and a broad complex in the region 300–340 mμ (Figure 18). The former band is shifted bathochromically on acidification. The spectra of the dihydrofuroquinolines are quite similar to the quinolines (268). Examples of the furoquinolines are shown (CXLVIIa–g). Acronidine (CL, R = H), an extended furoquinoline, has maxima at 253 (log ε 4.7) and 335 mμ (4.2, broad band) (269).

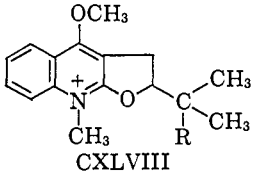


CXLVII

		6	7	8
a	Evolatine	OCH_3	$OCH_2CH(OH)C(OH)(CH_3)_2$	...
b	Evolitrine	...	$-OCH_3$	...
c	Evoxine	...	$OCH_2CH(OH)C(OH)(CH_3)_2$	OCH_3
d	Flindersiamine		$-OCH_2O-$	OCH_3
e	Kokusaginine	...	$-OCH_2O-$	
f	Maculine		$-OCH_2O-$	...
g	Maculosidine	OCH_3	...	OCH_3
h	6-Methoxydictamnine	OCH_3	...	...
i	Skimmiamine	...	$OCH_2CH(OH)C(OH)(CH_3)_2$	...
j	Maculosine		$-OCH_2O-$	...

Position 4 = $OCH_2CH(OH)C(OH)(CH_3)_2$

The spectrum of 6-methoxydictamnine (CXLVIIh), recently published (338), has an unusually high log ε value (6.10) at 240 mμ. The dihydrofuroquinolines (CXLVIII) isolated as salts can be regarded as trans-



CXLVIII

a Lunasine R = H
b O-Methylbalfourodinium salts R = OH

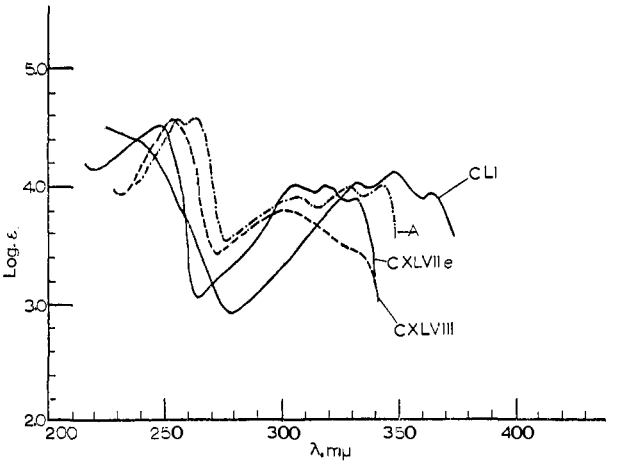
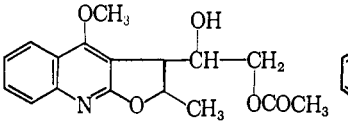


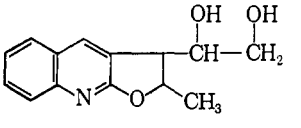
Figure 18.—Quinoline group: (A) isokokusaginine (CLII, 7,8-methylenedioxy) in ethanol; kokusaginine (CXLVIIe) in ethanol; lunasine (CXLVIII) perchlorate in ethanol; flindersine (CLI) in ethanol.

formation products of the dihydrofuro-4-quinolones (273). The spectra with maxima at 254 (log ε 4.6) and at 303 mμ (log ε 3.8) (broad) are similar to the quinolines (Figure 18).

Other examples of the dihydrofuroquinolines are the alkaloids dubininine (CLXVI) and dubinidine (CLXVII).



CLXVI



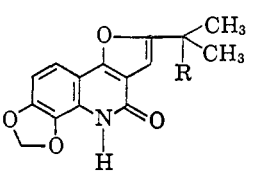
CLXVII

The published ultraviolet spectra (46) have very high absorbance values which do not appear to be consistent with the substituted quinoline ring system.

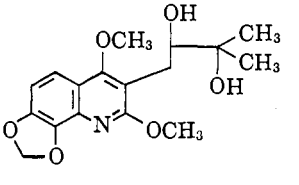
F. DEHYDROPYRANO-2-QUINOLONES (FLINDERSINE)

The spectrum of flindersine (CLI) (Figure 18), is similar to that of the furoquinolines. Dihydroflindersine with maxima at 225, 272, 283, and 312 mμ is similar to 4-hydroxy- and 4-methoxy-2-quinolones (268).

The angular furoquinoline structures, *e.g.*, orixidine (CLXVIII, R = H) and orixidinine (CLXVIII, R = OH), have been established (247) as degradation products of the alkaloid orixane (CLXIX). It is not unlikely that structures of this type will be found naturally occurring. The spectra of the angular furoquinolines are similar to the dehydropyrano-2-quinolones.



CLXVIII



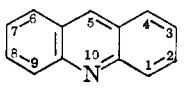
CLXIX

TABLE XX

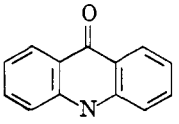
Compound	$\lambda_{max.}$ mμ	Log ε	$\lambda_{min.}$ mμ	Log ε	Solvent[a]	Ref.
		Acridines				
Acridine	250, 328 sh, 339, 349, 359, 370, 384	4.23, 2.50, 2.83, 2.86, 2.96, 2.74, 2.44	223, 291, 344, 351, 366, 380	2.95, 1.78, 2.77, 2.79, 2.72, 2.40	E	271
	257, 318 sh, 346 sh, 356, 390, 420 sh	5.01, 3.27, 4.04, 4.32, 3.66, 3.34	284	2.38	H^+ (0.5 *N*)	99
		Acridones				
Acridone	251, 254, 295, 308, 370 sh, 381, 400	4.76, 4.78, 3.33, 3.05, 3.63, 3.93, 3.95	292, 321, 390	3.25, 2.64, 3.79	E	68
Acronycine	281, 293, 309 sh, 392	4.57, 4.55, 4.27, 3.72, 3.82	287, 353	4.52, 3.38	E	68
2,4-Dimethoxy-10-methylacridone	250 sh, 261, 267, 290, 315 sh, 380	4.50, 4.66, 4.67, 4.15, 3.75, 3.94	283, 315, 340	4.02, 3.70, 3.10	E	222
Evoxanthine	212, 239 sh, 274, 322 sh, 385 sh, 399	4.22, 4.23, 4.67, 3.57, 3.90, 3.95	227, 339	4.07, 3.21	M	274
	210 sh, 238, 263, 280, 343 sh, 358, 406 sh	3.91, 4.37, 4.54, 4.67, 3.96, 4.20, 3.81	...	...	H^+ (0.2 *N*)	274
Melicopicine	269, 300, 403	4.73, 3.82, 3.88	340	2.9	E	68
Melicopidine	277, 317 sh, 399	4.66, 3.66, 3.89	350	3.18	E	68
Milicopine	252 sh, 270, 303, 388 sh, 409	4.40, 4.70, 4.13, 3.64, 3.82	354	3.07	E	68

XIII. ACRIDINE ALKALOIDS

The acridine alkaloids can be classified in two main types. These are the acridines (CLXX) and the acridones (CLXXI). Most of the alkaloids in this group



CLXX



CLXXI

are of the acridone type (see Table XX).

A. ACRIDINES

The alkaloid dubamine has been assigned the structure of a 1,2-methylenedioxyacridine. Acridine (Figure 19) has a maximum at ~250 mμ (log ε 4.2) and a broad complex band from ~340 to 380 mμ (log ε ~2.8). On acidification, the latter band is broadened and shifted bathochromically. The spectra of the hydroxyacridines have also been described (6).

B. ACRIDONES

The spectra of the acridones (CLXXI) are characterized by two main regions of absorption, at 250–270 and 390–410 mμ. There is generally a subsidiary band or shoulder at ~295–310 mμ.

Examples of the acridones are shown below and in Figure 20.

The spectra of the acridones bear similarities to the 4-quinolones, but with the long wave length band, however, being observed at longer wave lengths in the acridones than in the 4-quinolones. On acidification the main short wave length band in evoxanthine (CLXXIc) shows a bathochromic shift, and the long wave length band shows a hypsochromic shift with increased intensity. The spectra of the group have been discussed from the molecular orbital point of view (68).

Acronycine, a dehydropyranoacridone (CLXXII or CLXXIII), with maxima at 280–290, 309 (sh), and 392 mμ is similar to the acridones.

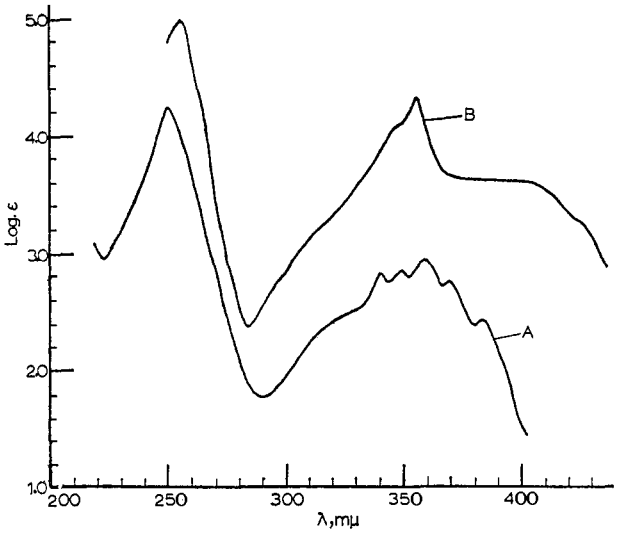


Figure 19.—Acridine: (A) acridine (CLXX) in ethanol; (B) acridine in 5 *N* hydrochloric acid.

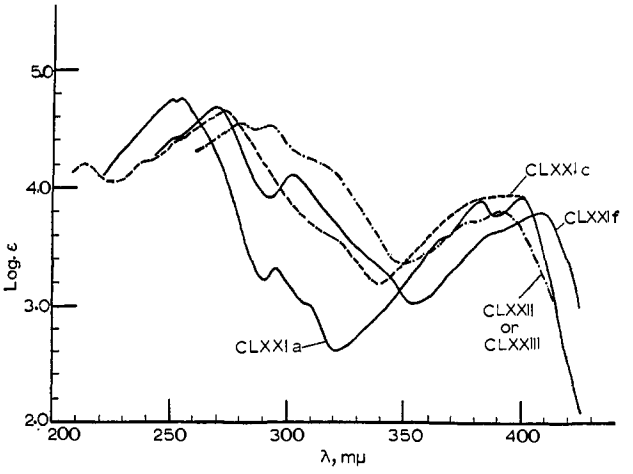
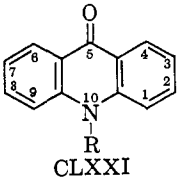
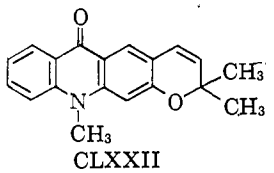


Figure 20.—Acridones: acridone (CLXXIa) in ethanol; evoxanthine (CLXXIc) in methanol; melicopine (CLXXIf) in methanol; acronycine (CLXXII or CLXXIII) in ethanol.

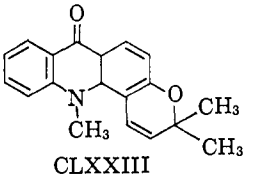


CLXXI

		R	1	2	3	4
a	Acridone	H	H	H	H	H
b	2,4-Dimethoxy-10-methylacridone	CH_3	H	OCH_3	H	OCH_3
c	Evoxanthine	CH_3	H	$-OCH_2O-$		OCH_3
d	Melicopicine	CH_3	OCH_3	OCH_3	OCH_3	OCH_3
e	Melicopidine	CH_3	OCH_3	$-OCH_2O-$		OCH_3
f	Melicopine	CH_3	$-OCH_2O-$		OCH_3	OCH_3
g	10-Methylacridone	CH_3	H	H	H	H
h	Xanthevodine	H	OCH_3	$-OCH_2O-$		OCH_2



CLXXII



CLXXIII

XIV. PHENANTHROQUINOLIZIDINE AND PHENANTHROINDOLIZIDINE ALKALOIDS

Members of this group are: cryptopleurine (CLXXIV); tylocrebrine (CLXXVa), R = R_2 = H, R_1 = R_3 = OCH_3; tylophorine (CLXXVb), R = R_3 = H, R_1 = R_2 = OCH_3; and tylophorinine (CLXXVc),

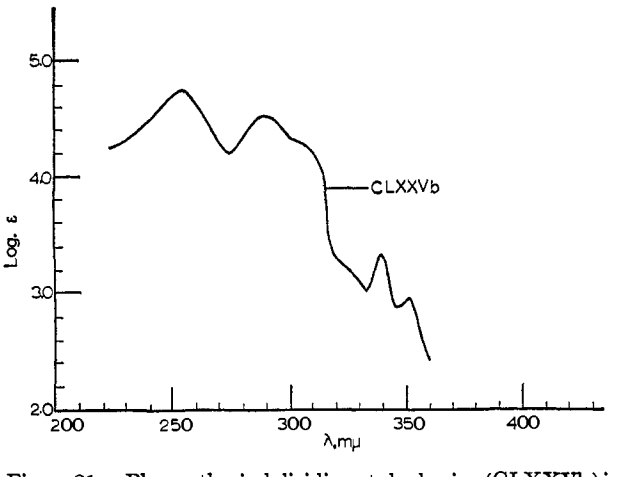
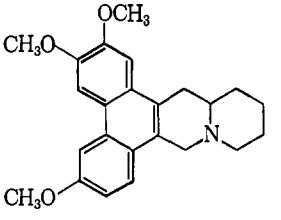
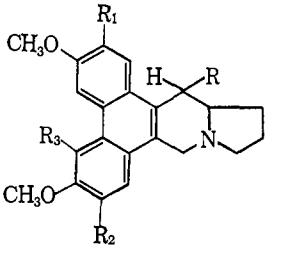


Figure 21.—Phenanthroindolizidine: tylophorine (CLXXVb) in ethanol.



CLXXIV



CLXXV

R = OH, R_1 = R_3 = H, R = OCH_3. These alkaloids show the ultraviolet spectrum of a substituted phenthrene, as is exemplified by tylophorine which has maxima at 255, 290, 340, and 353 mμ (log ε 4.74, 4.49, 3.30 and 2.93) (Figure 21). From the values given in the Table XXI, a comparison of tylophorine and tylocrebine shows that the methoxyl-substitution pattern does have some effect on the ultraviolet spectra of these compounds. The spectrum of cryptopleurine is unaffected by dilute acid or alkali (151).

XV. INDOLE AND DIHYDROINDOLE ALKALOIDS

The indole and dihydroindole group contains the largest number of alkaloids and although divisions have been made on the basis of the plant source, for example, *Ergot*, *Strychnos*, *Vinca*, *Rauwolfia*, *Iboga*, and *Aspidosperma* species (298), it is preferable here to group these alkaloids into the different related chromophores, a

TABLE XXI

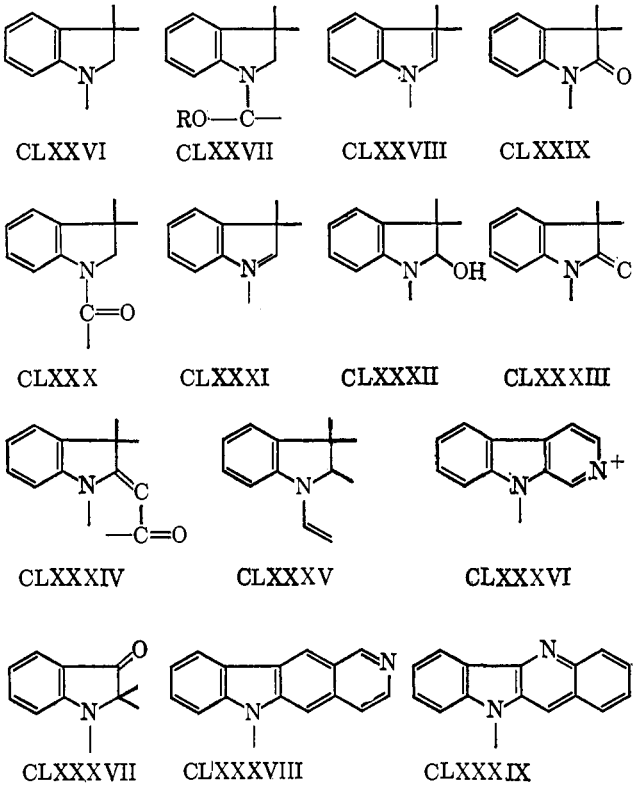
PHENANTHROQUINOLIZIDINE AND PHENANTHROINDOLIZIDINE

Compound	λ_{max}, mμ	Log ε	Solvent	Ref.
Cryptopleurine	258, 286, 343, 359	4.62, 4.40, 2.96, 2.68	E	151
3,4-Dimethoxy-1-(dimethylaminoethyl)-phenanthrene methiodide	253 sh, 257, 278, 305, 313	4.70, 4.73, 4.05, 4.09, 4.09	E	96
Tylocrebrine	263, 342, 360	4.81, 3.25, 3.09	E	149
Tylophorine	255, 290, 340, 353 (λ_{min} 275, 333, 345)	4.74, 4.49, 3.30, 2.93 (4.20, 3.01, 2.86)	E	165
Tylophorinine	258, 286, 343, 359	4.62, 4.40, 2.96, 2.68	E	165

method used in reviews on indole and dihydroindole alkaloids (31, 40, 207, 298).

The related chromophores are: (A) indolines (or dihydroindole) (CLXXVI), (B) N-hydroxyalkylindoline or its ethers (CLXXVII), (C) indoles (CLXXVIII) (which includes some extended indoles but not indoles with the quinazoline group), (D) oxindoles (CLXXIX), (E) N-acylindolines (CLXXX), (F) indolenines (CLXXXI), (G) carbinolamines (CLXXXII), (H) methyleneindolines (CLXXXIII) and the akuammicine group (CLXXXIV), (I) vinylindoline (CLXXXV), (J) β-carboliniums (CLXXXVI), (K) ψ-indoxyls (CLXXXVII), (L) pyridocarbazoles (CLXXXVIII), and (M) quinindoles (or cryptolepine type) (CLXXXIX).

It is of interest to note the close correlation between the color reaction with ceric sulfate and the ultraviolet chromophore of the alkaloids of the *Calabash curare* and *Strychnos* species (31, 32). It should be pointed out that it is difficult to distinguish with certainty by spectroscopic methods between the chromophores CLXXVII and CLXXXII or between CLXXXIII and CLXXXV.



A. INDOLINES

These alkaloids usually have two distinct bands at about 245 and 295 mμ, and desacetylaspidospermine (CXC) (Figure 22) is typical of this group. The effect of acid on the dihydroindole alkaloids depends on the distance between N(a) and N(b) (169). Where more than three carbon atoms separate N(a) and N(b) the

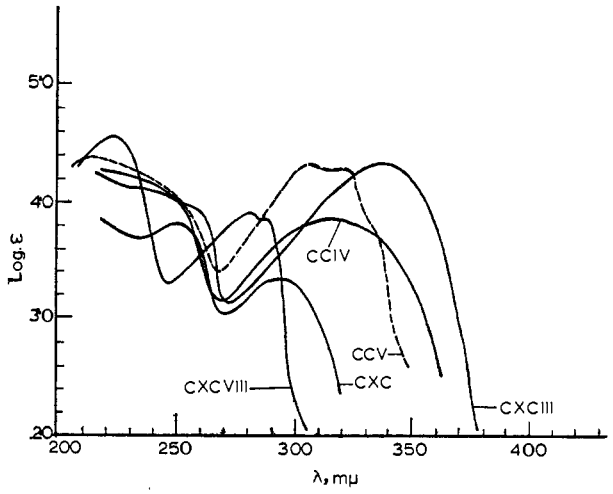
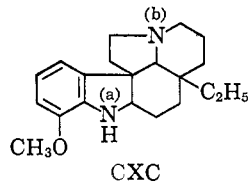


Figure 22.—Indoles and dihydroindoles: desacetylaspidospermine (CXC) in ethanol; ochropine (CXCIII) in ethanol; 3-epi-β-yohimbine (CXCVIII) in ethanol; ergotamine (CCIV) in ethanol; uleine (CCV) in ethanol.

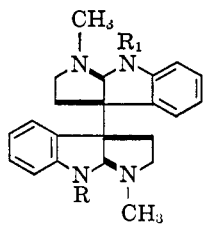


CXC

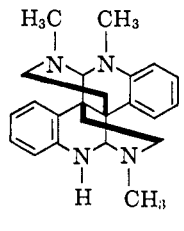
indoline absorption changes to a benzenoid type. This is due to the fact that the positive charge on the protonated N(b) is sufficiently far away from N(a) so as not to prevent it from being protonated in dilute acid. The indoline-type absorption is retained in acid solution if N(a) and N(b) are nearer than three carbon as N(a) becomes practically nonbasic as a result of the positive charge on N(b) (190).

Substitution on the aromatic ring may markedly affect the indoline-type ultraviolet absorption spectrum (82, 285).

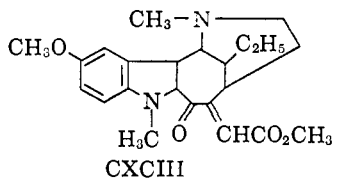
The Calycanthaceous alkaloids calycanthidine (CXCI, R = H; R_1 = CH_3), folicanthine (CXCI, R = R_1 = CH_3), and chimonanthine (CXCI, R_1 = R = H) are included here. Their ultraviolet spectra correspond to



CXCI



CXCII



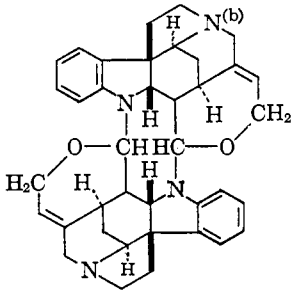
CXCIII

a Ph–N–C(=)–N– chromophore but are similar to the indolines. Calycanthine (CXCII), which has a quinoloquinoline skeleton, is also included here because of its ultraviolet spectral similarities to the indolines.

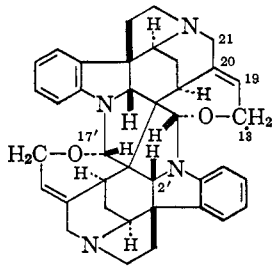
Ochropine (CXCIII) is a special case of the indoline chromophore which is extended to 337 mμ (log ε 4.36) by the presence of an α,β-unsaturated keto acid ester in a seven-membered ring system adjacent to the dihydroindole (Figure 22).

B. N-HYDROXYALKYLINDOLINE OR ITS ETHERS

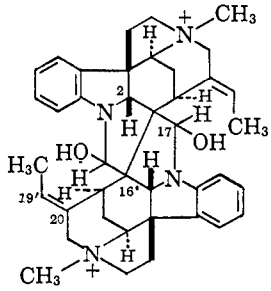
Caracurine V, with the aminohemiacetal structure CXCIV, caracurine II (CXCV), and C-alkaloid D (CXCVI) are members of this group. These alkaloids have quite similar ultraviolet spectra, and caracurine II with λ_{max} 246 and 291 mμ (log ε 4.22 and 3.73) is unaffected in 2 *N* hydrochloric acid–ethanol (33). C-Alkaloid D undergoes a bathochromic shift in alkali, a fact in keeping with its N-hydroxyalkylindoline chromophore. In 12 *N* hydrochloric acid, the ultraviolet spectrum is completely changed, and this is probably due to the formation of the chromophore CXCVII.



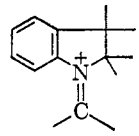
CXCIV



CXCV



CXCVI

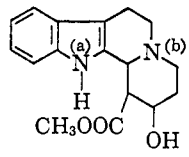


CXCVII

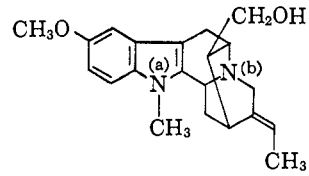
C. INDOLES

Four subdivisions have been made of the indole chromophore: (i) indoles with unsubstituted aromatic rings; (ii) a single substituent on the aromatic ring; (iii) two substituents on the aromatic ring; and (iv) extended indoles.

Most unsubstituted indole alkaloids show two major bands, one at ~226 mμ and a second band between 280 and 292 mμ with the latter maximum usually displaying fine structure. 3-Epi-β-yohimbine (CXCVIII) (Figure 22) exemplifies a typical indole spectrum.

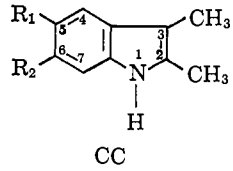


CXCVIII

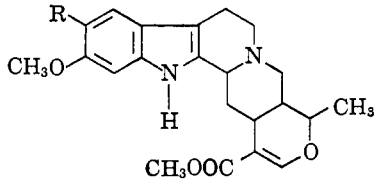


CXCIX

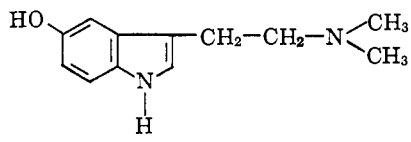
The nature of N(b) has an influence on the ultraviolet spectrum. For example the N(b) quaternary iodide of lochnerine (CXCIX) absorbs 9 to 10 mμ lower than the tertiary base (12). Substitution on the aromatic ring affects the indole chromophore. A single substituent in general shifts the long wave length band still higher, and two substituents increase this shift. Good models to illustrate this effect are 2,3-dimethylindole (CC, $R_1 = R_2 = H$), 2,3-dimethyl-6-methoxyindole (CC, $R_1 = H$; $R_2 = OCH_3$), 2,3-dimethyl-5,6-dimethoxyindole (CC, $R_1 = R_2 = OCH_3$), isoreserpine (CCI, R = H), and isoreserpiline (CCI, R = OCH_3) (see Table XXII for values).



CC



CCI



CCII

The influence of alkali on the phenolic indole is exemplified by the bathochromic shift experienced by bufotenine (CCII). Bufotenine which has a λ_{max} 277 mμ with a shoulder at 295 mμ (λ_{min} 249 mμ) in 0.1 *N* sodium hydroxide displays a shift of the shoulder to give a definite maximum at 322 mμ (322). The "dimeric" indole–indoline alkaloids vinblastine (CCIII, R_1 = $COOCH_3$; $R_2 = CH_3$; $R_3 = OCH_3$; $R_4 = COCH_3$) and vincristine (CCIII, $R_1 = COOCH_3$; R_2 = CHO; R_3 = OCH_3; $R_4 = COCH_3$) are of considerable interest in medicine, and these recently elucidated structures (58, 251) have normal indole spectra. The ultraviolet spectra of some indoles have been discussed by Raymon-Hamet (277).

The effect of extending the basic indole chromophore in a variety of ways can be seen by considering the ultraviolet spectra of ergotamine (CCIV), uleine (CCV), (Figure 22), eburnamonine (CCVI), eburnamenine (CCVII), isovobasine (CCVIII, R = R_1 = H), harmaline (CCIX), hortiamine (CCXa), and hortiacine and alstoniline hydrochloride (CCXI) (see Figure 23). Hortiacine, like hortiamine, also contains a quinazoline

TABLE XXII[a]

INDOLES AND DIHYDROINDOLES

Compound	λ_{max}, mμ	Log ε	Solvent (see Table I)	Ref.
	A. Indolines			
Ajmalidine	248, 294	3.93, 3.46	M	249
Ajmaline (rauwolfine)	248, 292	3.94, 3.49	M	249
Calycanthidine	250, 308	4.18, 3.78	E	299
	243, 298	4.17, 3.70	H^+	
Calycanthine	250, 309	4.28, 3.80	E	184
	240, 293, 302	4.30, 3.72, 3.73	H^+	
Chimonanthine	245, 302	4.15, 3.78	E	184
	240, 294	4.14, 3.72	H^+	
Desacetylaspidospermine	250, 295	3.80, 3.34	E	209
	(λ_{min} 235, 272)	(3.68, 3.02)		
Desacetylpyrifolidine[j]	292	3.49	E	249[a]
Epiquinamine	243, 300	3.7, 3.3	E	105
Eseramine	256, 311	4.11, 3.42	E	285
dl-Eseroline	242, 315	4.0, 3.5	B, pH 6.8	177
Fendleridine	242.5, 292.5	3.86, 3.48	E	75
Folicanthine	254, 311	4.25, 3.83	E	190
	Hypochromic shift of 8 mμ		H^+	
Huntercorymine[p]	257, 314	4.06, 3.59	E	249
Isoajmaline	249, 285	3.9, 3.4	E	345
Kopsinilam[x]	244, 294	3.87, 3.45	E	249
Kopsinine[y]	244, 295	3.83, 3.45	E	249
7-Methoxy-N-methylindoline[q]	214, 252, 290	4.53, 3.92, 3.36	E	249
Ochropine[dd]	337	4.35	E	249
	(λ_{min} 273)	(3.16)		
Physostigmine	252, 310.5	4.08, 3.44	E	285
Physovenine	252, 310	4.12, 3.51	E	285
Pleiocarpinilam[x]	253, 297	3.98, 3.46	E	249
Pleiocarpinine (pleiocinine)[y]	253, 299	3.95, 3.51	E	249
Quebrachidine[m]	242, 291	3.81, 3.47	E	249
Quinamine	245, 299	4.0, 3.4	E	105
Rauvomitine[o]	208, 252	4.76, 4.19	M	249
Strychnidine	264, 317	4.12, 3.55	E	209
Tetraphyllicine[g]	249, 293	3.92, 3.47	M	249
Toxiferine dichloride[u]	291	4.53	E	249
Vallesine	211, 250	4.47, 3.94	?	301
Vindorosine[ee]	206, 249, 304	4.32, 3.99, 3.48	E	249
Vomalidine[q]	253, 292	3.91, 3.38	M	249
	B. N-Hydroxyalkylindolines			
C-Alkaloid D chloride	242, 282	3.78, 3.20	W	209
Caracurine II	246, 291	4.22, 3.73	E	33
Caracurine V chloride	256, 292	3.85, 3.50	W	16
	256, 290	3.80, 3.77	H^+ (0.05 *N*)	
	C. Indoles			
	(i) Unsubstituted Aromatic Ring			
Affinisine[vv]	227, 284	4.57, 3.83	E	249
Ajmalicine[w]	226, 291	4.65, 3.81	M	249
Akuammidine[z, rr]	225, 280	4.55, 3.90	E	249
Akuammigine	229, 274, 290	4.53, 3.95, 3.80	?	286
Alloyohimbine[r]	225, 290	4.51, 3.74	M	249
Cinchonamine[zz]	223, 292	4.60, 3.88	M	249
Coronaridine hydrochloride[m] (carbomethoxyibagomine hydrochloride)	224, 285	4.51, 3.91	E	249
Corynantheidine[qq]	226, 281	4.65, 3.89	E	249
Corynantheine[r]	227, 291	4.64, 3.79	M	249
Corynanthine	226, 290	4.54, 3.77	M	249
Deserpidine	216, 271, 289	4.78, 4.25, 4.06	M	249
Dihydrocorynantheine[qq]	226, 281	4.64, 3.88	E	249
Dihydrocorynantheol[j]	225, 282, 290	4.60, 3.91, 3.85	E	249
2,3-Dimethylindole	226, 282, 290	4.44, 3.79, 3.74	E	249

TABLE XXII (*Continued*)

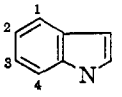
Compound	$\lambda_{max.}$ mμ	Log ε	Solvent (see Table I)	Ref.
Eburnamine[uu]	228, 282	4.49, 3.88	E	249
Epi-3-corynanthine[r]	224, 282	4.48, 3.83	E	249
Epi-α-yohimbine[oo]	225, 290	4.48, 3.77	M	249
3-Epi-β-yohimbine[h]	224, 282, 289 (λ_{min} 242)	4.57, 3.92, 3.85 (3.32)	E	249
Geissoschizine[d]	222, 266	4.61, 4.18	E	249
Gramine[gg]	217, 280	4.58, 3.79	E	249
Isoeburnamine[uu]	227.5, 281.5	4.51, 3.89	E	249
Isoraunescine[qq]	216, 268	4.74, 4.18	M	249
Isovobasinol[kk]	224, 285, 294	4.52, 3.94, 3.87	E	249
Ibogamine[s]	227, 291.5	4.52, 3.86	M	249
Mayumbine	228, 280, 290	4.12, 3.95, 3.82	?	286
Melinonine chloride[ww]	219, 288	4.61, 3.77	E	249
Polyneuridine[g]	226, 281	4.53, 3.83	E	249
Pseudoyohimbine[r]	225, 290	4.54, 3.80	M	249
Raunescine[qq]	218, 291	4.81, 4.05	M	249
Rauniticine[qq]	226, 282	4.61, 3.86	E	249
Rauwolscine[f]	226, 291	4.55, 3.78	M	249
Serpine[f]	226, 290	4.55, 3.80	M	249
Tetrahydroalstonine[t]	226, 291	4.64, 3.83	M	249
Tetrahydroharman[aa]	225, 291	4.51, 3.75	M	249
Tetrahydroserpentine[c]	227, 292	4.61, 3.79	M	249
Vinblastine etherate (vincaleukoblastine)	214, 259, 290	4.73, 4.21, 4.15	E	249
Vincristine sulfate (leurocristine)	220, 255, 296	4.65, 4.21, 4.19	E	249
Voacamine[s]	225, 294	4.76, 4.29	M	249
Voachalotine[cc]	228, 283	4.62, 3.88	E	249
Vobasinol[kk]	221, 284, 294	4.45, 3.89, 3.83	E	249
β-Yohimbine[r]	225, 290	4.57, 3.80	M	249
Yohimbine	226, 291	4.56, 3.80	M	249
(ii) One Substituent 				
(a) 1-OH				
Psilocine[q]	222, 268, 285, 294	4.58, 3.75, 3.67, 3.65	E	249
Psilocybine[q]	220, 266	4.55, 3.78	E	249
(b) 2-OH				
Bufotenine[gg]	223, 277, 300	4.34, 3.79, 3.66	E	249
	277, 296	3.74, 3.67	H^+ (0.1 *N*)	321
	218, 276, 323	4.37, 3.74, 3.65	OH^- (0.1 *N*)	
Sarpagine[ss]	226, 277	4.34, 3.89	E	249
(c) 2-OCH_3				
Aricine[r]	227, 279	4.54, 3.98	M	249
2,3-Dimethyl-5-methoxyindole	227, 284	4.38, 3.88	E	249
Ibogaine[r]	226, 298	4.39, 3.93	M	249
Lochnerine[z]	227, 280	4.43, 3.93	E	249
Raumitorine[s]	228, 279	4.54, 3.95	M	249
Voacangarine[q]	222, 282	4.44, 3.95	E	249
Voacangine[s]	225, 285	4.46, 3.97	M	249
Voacristine[tt]	223, 282	4.46, 3.98	E	249
(d) 3-OCH_3				
2,3-Dimethyl-6-methoxyindole	229, 274, 299	4.51, 3.63, 3.69	E	249
Isoreserpinine tartrate	227, 296	4.61, 3.79	M	249
Isovoacangine	227, 299	4.54, 3.87	E	249
Poweridine	226, 270, 296	4.56, 3.70, 3.79	E	249
Pseudoreserpine	217, 266, 293	4.77, 4.23, 3.99	M	249
Raugustine	215, 267, 291	4.74, 4.19, 3.98	E	249
Raujemidine	216, 266, 294	4.78, 4.22, 4.02	E	249
Raunitidine	288, 298	4.61, 3.75	E	249
Renoxidine	216, 266, 290	4.79, 4.21, 4.04	E	249
Rescidine	228, 302	4.74, 4.41	E	249
Rescinnamine	228, 302	4.78, 4.47	M	249

TABLE XXII (*Continued*)

Compound	λ_{max}, mμ	Log ε	Solvent (see Table I)	Ref.
Reserpiline	229, 300, 304	4.57, 4.03, 4.03	E	191
Reserpine	216, 267, 296	4.74, 4.19, 3.98	M	249
Reserpinine	228, 296	4.64, 3.81	M	249
Tabernanthine	228, 299	4.53, 3.76	M	249
Tetrahydroalstoniline	228, 296	4.68, 3.92	M	249
Tetraphylline	228, 296	4.66, 3.82	M	249
	(iii) Two Substituents on Aromatic Ring			
Conopharyngine[kk]	224, 304	4.46, 4.05	E	249
2,3-Dimethyl-5,6-dimethoxyindole	226, 302	4.40, 3.91	E	249
Ibogaline	228, 304	4.43, 4.01	E	249
Isoreserpiline[l] (elliptine)	227, 304	4.59, 4.05	E	249
Rauwanine[n]	227, 298	4.52, 3.96	E	249
Reserpiline oxalate[q]	225, 303	4.57, 4.00	M	249
Seredine[s]	227, 305	4.45, 3.95	M	249
	(iv) Ring Substituent			
Agroclavine	225, 284, 293	4.47, 3.88, 3.81	E	318
Elymoclavine	227, 283, 293	4.31, 3.84, 3.76	E	318
	(v) Extended Indoles			
Alstoniline hydrochloride[i]	213, 391 (λ_{min} 280–320)	4.52, 4.54 (3.68)	M	249
Eburnamenine picrate[uu]	222, 258, 312, 358 (λ_{min} 237, 285, 325)	4.56, 4.54, 4.14, 4.21 (4.36, 3.90, 3.86)	E	249
Eburnamonine[uu]	242, 266, 302.5	4.27, 3.98, 3.65	E	249
Ergotamine	318, 245 sh (λ_{min} 270)	3.86 (3.16)	E	320
Harmaline[ll]	218, 260, 344, 376 (λ_{min} 213, 245, 283, 370)	4.27, 3.90, 4.11, 4.02 (4.26, 3.84, 3.24, 4.01)	M	249
Harmaline hydrochloride	324	4.32	E	345
Hortiamine[qq]	320, 376	4.17, 4.24	E	249
Isopenniclavine	242, 313	4.31, 3.94	E	192
Isovobasine[kk]	237, 320 (λ_{min} 267)	4.18, 4.27 (3.34)	E	249
Ochropamine	243, 215	4.27, 4.24	E	115
Ochropine	236, 258.337	4.15, 3.90, 4.35	E	115
Penniclavine	240, 315	4.29, 3.93	E	318
Uleine[pp]	350 (λ_{min} 270)	4.32 (3.4)	E	249
Vobasine[kk]	239, 316	4.20, 4.27	E	249
	D. Oxindoles			
	Unsubstituted Aromatic Ring			
Corynoxeine[n]	206, 244	4.52, 4.25	E	249
Corynoxine[n]	207, 244	4.50, 4.25	E	249
Formosanine[n,bb]	206, 244	4.52, 4.21	E	249
Gelsemine[bb]	210, 252, 280 sh (λ_{min} 225)	4.50, 3.86, 3.14 (3.22)	E	249
Isorhyncophylline[ww]	207, 244	4.46, 4.25	E	249
Mitraphylline[bb]	209, 242	4.46, 4.18	M	249
Rhyncophylline[bb]	207, 243	4.51, 4.24	M	249
	E. N-Acylindolines			
	(i) –C=O in Ring System			
	(a) Unsubstituted			
Eburnamonine[uu]	242, 266, 302.5	4.27, 3.98, 3.66	E	249
Strychnine	254, 278, 288	4.10, 3.63, 4.54	E	249
	(b) Substituted			
Brucine	267, 301	4.08, 3.93	E	249
α-Colubrine	250, 288	4.05, 3.81	?	10
Schizogaline	219, 254, 301	4.27, 3.90, 3.79	E	249
Schizozygine[mm]	267, 313	3.9, 3.75	E	280
Vomicine hydrochloride	222, 263, 297	4.27, 3.76, 3.51	E	249

TABLE XXII (*Continued*)

Compound	$\lambda_{max.}$ mμ	Log ε	Solvent (see Table I)	Ref.
	(ii) N-Acetyl			
	(a) Unsubstituted			
Diaboline hydrochloride	253, 287 sh (λ_{min} 227)	4.06, 3.37 (3.76)	E	19
	(b) Substituted Aromatic Ring			
Aspidocarpine[hh]	226, 262, 297	4.40, 3.90, 3.21	E	249
Aspidospermine[zz]	218, 255	4.52, 4.04	M	249
Cyclindrocarpidine[h]	218, 255.5	4.53, 4.06	E	249
Demethylaspidospermine	220, 258, 293	4.39, 3.52, 3.20	E	132
	307	3.97	OH^-	
Spegazzinidine[h]	224, 260	4.39, 3.93	E	249
Spegazzinine[h]	219, 257, 289	4.37, 3.87, 3.40	E	249
Strychnospermine[b]	220, 249, 293	4.48, 4.02, 3.75	E	249
	(iii) N-Carbomethoxy			
	(a) Unsubstituted Aromatic Ring			
Kopsine	240, 278, 286	4.08, 3.37, 3.35	E	166
Pleiocarpine	245, 282	4.15, 3.44	E	249
	(iv) N-Formyl			
	(a) Unsubstituted Aromatic Ring			
Aspidofractine[h]	253, 289	4.07, 3.64	E	249
Refractidine[g]	254, 279, 288	4.11, 3.63, 3.59	E	249
	(b) Substituted Aromatic Ring			
Vallesine[uu]	217, 258	4.49, 4.14	E	249
	(v) N-Propanoyl			
	(a) Substituted Aromatic Ring			
Aspidoalbine[q]	226, 267	4.33, 4.04	E	249
Aspidolimine[hh]	226, 264, 297	4.39, 3.90, 3.26	E	249
Fendlerine	220, 225, 258, 300	4.23, 4.25, 3.55, 3.38	E	74
Haplocine	219.5, 258, 292	4.44, 3.95, 3.57	E	78
	F. Indolenies			
Vomilenine (alkaloid F_2)[q]	218, 257 (λ_{min} 236)	4.35, 3.74 (3.58)	E	249
	G. Carbinolamines			
C-Alkaloid A Chloride	250, 290	4.05, 3.40	W	209
C-Alkaloid F Chloride	249, 296	4.05, 3.45	W	209
C-Calebassine dichloride	214, 259, 306 (λ_{min} 227, 277)	4.46, 4.35, 3.74 (3.7, 3.18)	E	40
	H. Akuammicine Type			
Akuammicine	227, 300, 330 (λ_{min} 265, 312)	4.09, 4.07, 4.24 (3.34, 4.04)	E	200
C-Fluorocurarine dichloride[u]	252, 298, 361 (λ_{min} 220, 270, 315)	3.95, 3.57, 4.16 (3.54, 2.84, 3.1)	E	249
Compactinervine[q]	237, 297, 332	4.0, 3.91, 4.18	E	249
Condylocarpine[q]	226, 296, 330	4.01, 3.98, 4.16	E	249
Minovincine[t]	227, 300, 327	4.03, 3.94, 4.14	E	249
Minovincinine[q]	224, 298, 328	3.99, 3.98, 4.10	E	249
Mossambine[q]	228, 298, 329	4.08, 4.03, 4.20	E	249
Norfluorocurarine[q]	244, 300, 365	3.96, 3.53, 4.28	E	249
	I. Vinylindolines			
	(i) C-Curarine Type			
Bisnor-C-curarine	264, 300	4.42, 4.14	E	244
Bisnortetrahydrocurarine	261, 300	4.37, 4.07	E	244
C-Alkaloid E dichloride	264, 291	3.84, 3.6	W	209
C-Alkaloid G dichloride	264, 292	3.47, 3.1	W	209
C-Curarine dichloride[e]	260, 295 (λ_{min} 282)	4.34, 3.97 (3.9)	E	249

TABLE XXII (*Continued*)

Compound	λ_{max}, mμ	Log ε	Solvent (see Table I)	Ref.
	(ii) C-Dihydrotoxiferine Type			
C-Alkaloid H (C-isodihydrotoxiferine)	292, 315 sh (λ_{min} 237)	4.54 (3.72)	W	39
C-Dihydrotoxiferine[u] (C-alkaloid K)	290, 321 sh (λ_{min} 235)	4.55 (3.6)	E	249
C-Toxiferine dichloride[u]	291, 320 sh	4.53	E	249
	J. Carboliniums			
Alstonidine[i]	238, 291, 360	4.66, 4.25, 3.74	E	249
Alstonine hydrochloride[i]	252, 309, 369	4.54, 4.36, 3.59	E	249
Harman[aa]	234, 287, 347	4.57, 4.21, 3.66	E	249
O-Methylharman (harmine)[zz]	241, 301, 336	4.61, 4.21, 3.69	M	249
N_b-Methylharman (melinonine F.)	250, 310, 370	4.51, 4.11, 4.16	E	18
Serpentine (salt)[i]	252, 308, 366	4.54, 4.33, 3.62	E	249
(base)[i]	284, 329, 425	4.69, 4.05, 3.45	E	249
	(i) Extended Carbazoles			
Canthinone	251, 259, 269, 293, 299, 347, 362, 381	4.09, 4.05, 4.03, 3.74, 3.90, 3.94, 4.17, 4.14	D	178
	(λ_{min} 255, 265, 280, 295, 319, 372)	(4.04, 4.04, 3.80, 3.92, 3.54, 3.40)		
4-Methylthiocanthinone	239, 253, 294, 306, ~350, 362, 380	4.42, 4.41, 4.22, 4.09, 4.03, 4.19, 4.14	D	248
Sempervirine[bb]	242, 295, 338, 383 (λ_{min} 276, 312, 357)	4.51, 4.11, 4.16, 4.16 (3.9, 3.92, 4.06)	M	249
Tuboflavine	215, 264, 289, 323, 401	4.59, 4.37, 4.38, 3.71, 3.97	M	218
	(λ_{min} 238, 274, 310, 347)	(4.02, 4.20, 3.62, 3.08)		
	K. ψ-Indoxyls			
Epiisoquinamine	241, 255, 395	4.2, 3.8, 3.5	E	105
Fluorocurine iodide	234, 271, 311, 412 (λ_{min} 261, 291, 338)	4.61, 3.92, 2.74, 3.78 (3.76, 2.46, 2.24)	W	209
Iboluteine	230, 420	4.30, 3.45	E	163
Isoquinamine	240, 255, 393, 410	4.4, 3.8, 3.6, 3.5	E	105
Isoreserpiline ψ-indoxyl	224, 251, 283, 405	4.36, 4.46, 4.06, 3.75	E	133
	L. Pyridocarbazoles			
Ellipticine	237, 285, 293, 335, 384, 405	4.32, 4.87, 4.85, 3.7, 3.61, 3.53	E	159
Ellipticine methiodide	276, 338, 375, 400, 520	4.46, 4.74, 3.92, 3.87	0.05 *N* OH^-	159
Methoxyellipticine[l]	244, 275, 291	4.39, 4.63, 4.70	E	249
N-Methyltetrahydroellipticine[p]	242, 263, 295, 328, 341	4.66, 4.32, 4.26, 3.59, 3.55	E	249
Olivacine	225, 240, 285, 290, 332, 380, 400	4.38, 4.28, 4.88, 4.86, 3.62, 3.58, 3.58	E	234
	(λ_{min} 235, 251, 288, 302, 360, 390)	(4.24, 4.18, 4.80, 3.46, 3.5, 3.52)		
Dihydroolivacine	238, 247, 276, 331, 346	4.44, 4.15, 4.64, 4.01, 3.66	E	153
	(λ_{min} 243, 256)	(4.40, 3.84)		
	M. Quinindole			
Cryptolepine methiodide	275, 280, 450 (λ_{min} 260, 310, 397)	4.81, 4.40, 3.52 (4.20, 3.30, 3.30)	E	150

[a] Reference 249 is to the Eli Lilly collection of spectra of indole and dihydroindole alkaloids (N. Neuss, Ed.) Where a lettered superscript appears beside a compound, there is an acknowledgment of the source of the sample used for the determination. Where no superscript appears beside the compound, this is an uncredited spectrum in the collection. [b] Anet, F. A. L. [c] Badger, F. E. [d] Bertho, A. [e] Boekelheide, V. [f] Chatterjee, A. [g] Djerassi, C. [h] Djerassi, C., and George, T. [i] Elderfield, R. C. [j] Gilbert, B. [k] Godtfredsen, W. O. [l] Goodwin, S. [m] Gorman, M. [n] Goutarel, R. [o] Haack, E. [p] Hochstein, F. A. [q] Hofmann, A. [r] Janot, M. M. [s] Janot, M. M., and Goutarel, R. [t] Janot, M. M., Le Men, J., and Plat, M. [u] Karrer, P. [v] Kim, K. A. [w] Klohs, M. W. [x] Kump, C. [y] Kump, W. [z] Le Men, J. [aa] Manske, R. H. [bb] Marion, L. [cc] Martin, R. H., and Pecher, J. [dd] Moore, B. P. [ee] Moza, B. K., and Trojanek, J. [ff] Müller, J. M. [gg] Pachter, I. J. [hh] Pinar, M. [ii] Popelak, A. [jj] Prelog, V. [kk] Prins, D. A. [ll] Rapala, R. T. [mm] Renner, U. [nn] Sandoval, A. [oo] Schlitter, E. [pp] Schmutz, J. [qq] Smith, E. [rr] Smith, G. F. [ss] Stoll, A. [tt] Stoll, W. G. [uu] Taylor, W. I. [vv] Weisbach, J. A. [ww] Wenkert, E. [xx] Witkop, B.

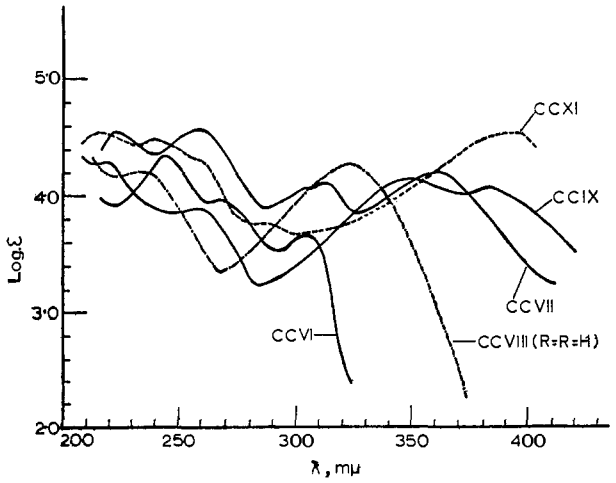


Figure 23.—Indoles and dihydroindoles: eburnamonine (CCVI) in ethanol; eburnamenine (CCVII) picrate in ethanol, isovobasine (CCVIII, R = R_1 = H) in ethanol; harmaline (CCIX) in methanol; alstoniline (CCXI) hydrochloride in methanol.

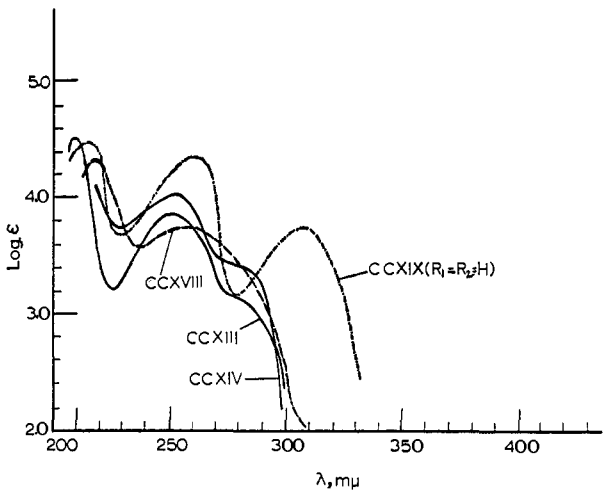
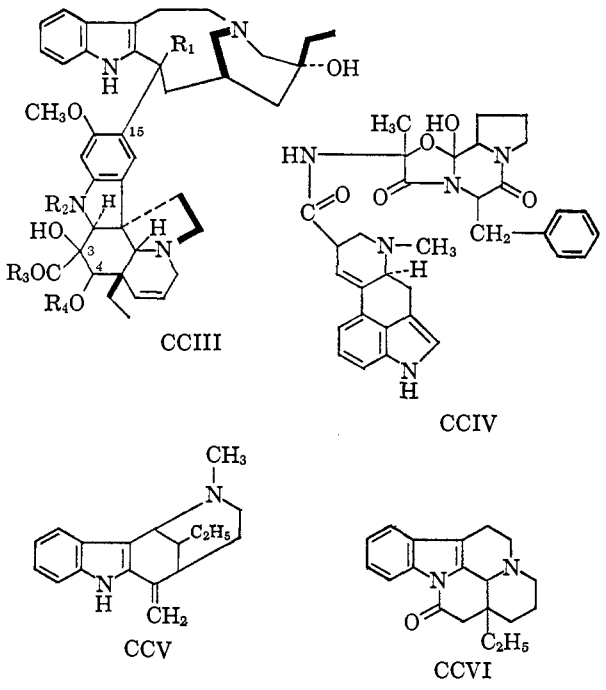
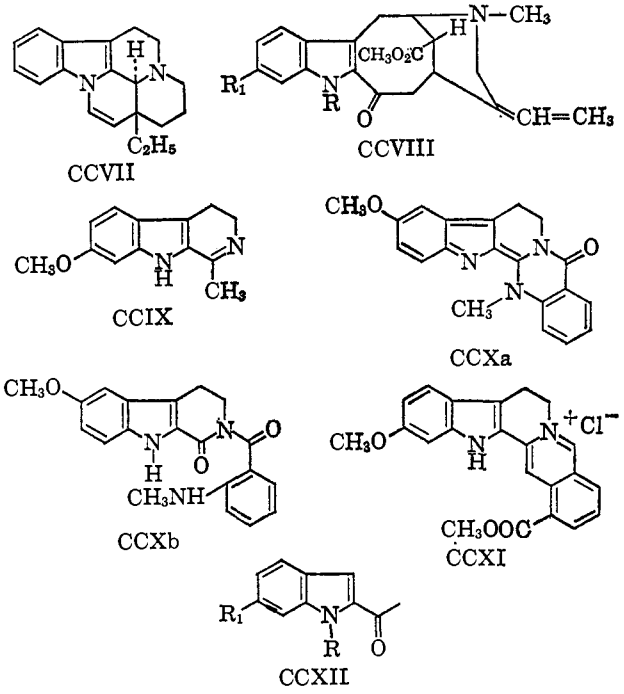


Figure 24.—Indoles and dihydroindoles: gelsemine (CCXIII) in ethanol; diaboline (CCXIV) in ethanol; vomilenine (CCXVIII) in ethanol; C-calebassine (CCXIX, R_1 = R_2 = H) dichloride in ethanol.





structure, and the former will be considered with the quinazoline group of alkaloids. Ochropamine (CCVIII, R = CH_3; R_1 = H), ochropine (CCVIII, R = CH_3; R_1 = OCH_3) (115), isovobasine (CCVIII, R = R_1 = H), and vobasine can be considered to form a distinct chromophoric subgroup, namely, the 2-acylindole group (CCXII). The methoxyl substituent on the aromatic ring of ochropine results in a strong bathochromic shift of the band at highest wave length, and this shift is further accentuated by the fact that the carbonyl group is in an eight-membered ring (115).

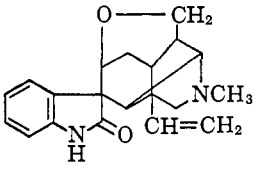
Hortiamine, a red-colored alkaloid, deserves special mention as it illustrates the marked effect of solvents on some chemical structure. In acetonitrile, hortiamine exists as CCXa, $C_{20}H_{17}N_3O_3$, and in alcohol as CCXb, $C_{20}H_{19}N_3O_3$ (249).

D. OXINDOLES

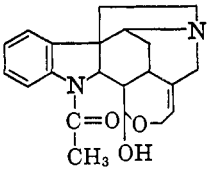
Some authors (298) group the oxindole and N-acylindolines together as there is a marked similarity in their ultraviolet spectra. There is, however, an important diagnostic feature which justifies their separation. All the oxindoles with an unsubstituted aromatic ring have a maximun between 206 and 210 mμ, while the N-acylinodolines show a corresponding maximum at higher wave length.

A typical oxindole, gelsemine (CCXIII), shows two bands (210 and 252 mμ, log ε 4.50 and 3.86) with a

shoulder at 280 mμ (Figure 24). The acyldihydroindole or oxindole C-alkaloid M has a spectrum which is not significantly changed just after the addition of alkali, but the shoulder at *ca.* 280 mμ becomes a well-defined maximum at 305 mμ (log ε 3.37) after standing with 0.1 *N* sodium hydroxide for 3 hr. (12).



CCXIII



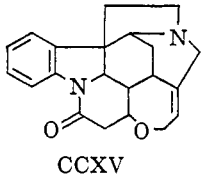
CCXIV

E. N-ACYLINDOLINES

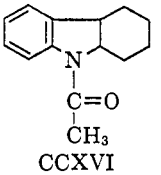
Division of alkaloids containing the N-acylindoline chromophore have been made strictly on the basis of their chemical structures (Table XXII), and no meaningful differentiation is possible on grounds of their ultraviolet spectra. The associated carbonyl group may be in a ring system, in a N-acetyl, N-carbomethoxy, N-formyl, or N-propanoyl group. When diaboline (CCXIV) (Figure 24) is deacetylated, the spectrum reverts to an indoline type, with maxima at 250 and 300 mμ. Brand and Scott (60) have drawn attention to the effect of conformation on the ultraviolet spectra of N-acylindolines. Strychnine (CCXV), with λ_{max} 254, 278, and 288 mμ (log ε 4.10, 3.63, and 4.54), has spectral similarities with hexahydrocarbazole (CCXVI) (λ_{max} 257, 281, and 290; log ε 4.20, 3.56, and 3.35), but is dissimilar to N-methylaceto-O-toluidide (CCXVII), λ_{max} 290 mμ (log ε 2.47), the difference being due to conformational dissimilarities.

F. INDOLENINES

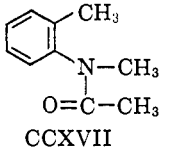
The spectrum of vomilenine (CCXVIII) (Figure 24) is characteristic of the indolenine chromophore which has two maxima at 218 and 257 mμ (log ε 4.35 and 3.74).



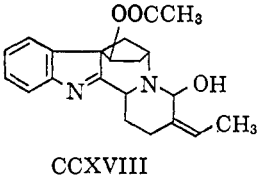
CCXV



CCXVI



CCXVII



CCXVIII

G. CARBINOLAMINES

Chemical evidence for the presence of the carbinolamine structures comes from the reductive elimination with zinc and acetic acid to yield the deoxy compound

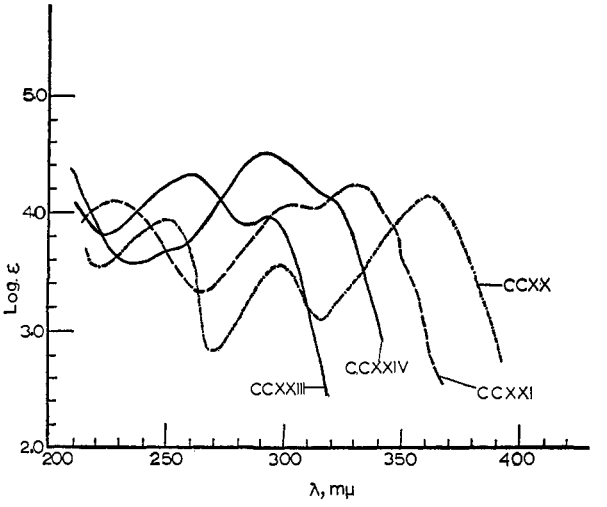
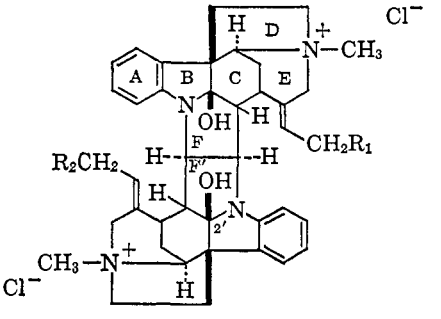


Figure 25.—Indoles and dihydroindoles: C-fluorocurarine (CCXX) chloride in ethanol; akummicine (CCXXI) in ethanol; C-curarine dichloride (CCXXIII) in ethanol; C-dihydrotoxiferine dichloride (CCXXIV) in ethanol.

(332). C-Calebassine (CCXIX, $R_1 = R_2 = H$) shows an ultraviolet spectrum which undergoes a bathochromic shift of 10 mμ in alkali which is supposed to be diagnostic of the 2-hydroxyindoline chromophore (142). C-Calebassine dichloride has three maxima, 214, 259, and 306 mμ (log ε 4.46. 4.35, and 3.74) (Figure 24), and in 10 *N* acid C-calebassine shows a band at ~320 mμ which is interpreted as the generation of a mesomeric cation (31, 43).

C-Alkaloid A (CCXIX, $R_1 = R_2 = OH$) and C-alkaloid F, (CCXIX, $R_1 = H$; $R_2 = OH$) are also members of this group.



CCXIX

H. METHYLENEINDOLINES AND THE AKUAMMICINE GROUP

These two groups are considered together, as the akuammicine group is an extension of the methyleneindoline chromophore. C-Fluorocurarine dichloride (CCXX), λ_{max} 252, 298, and 361 mμ, and akummicine (CCXXI), λ_{max} 227, 300, and 330 mμ (Figure 25), illustrate the effect of slight structural changes on a particular chromophore. The bands at 252 and 361 mμ show a marked bathochromic shift with respect to the

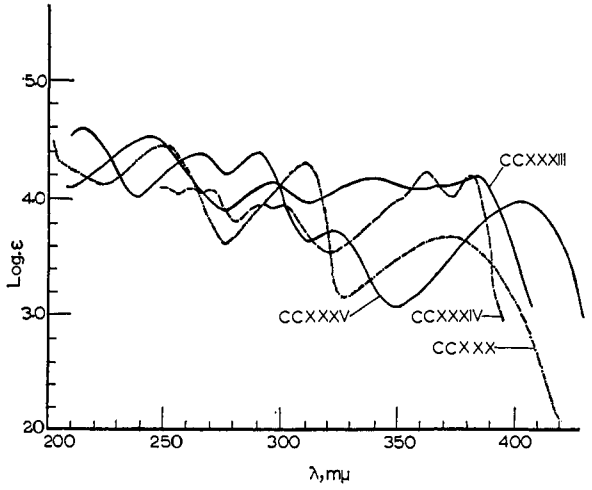
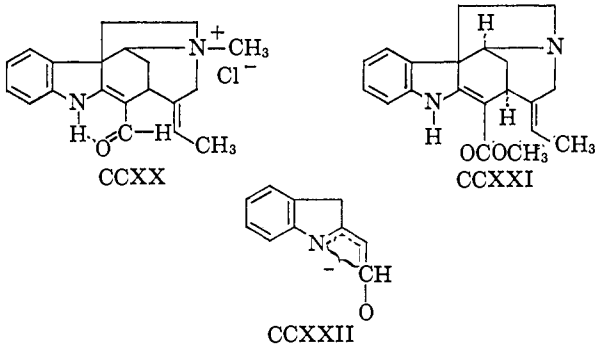


Figure 26.—Indoles and dihydroindoles: melinonine F (CCXXX, C_1 methyl) in ethanol; semperivirine (CCXXXIII) in methanol; canthinone (CCXXXIV) in dioxane; tuboflavine (CCXXXV) in methanol.

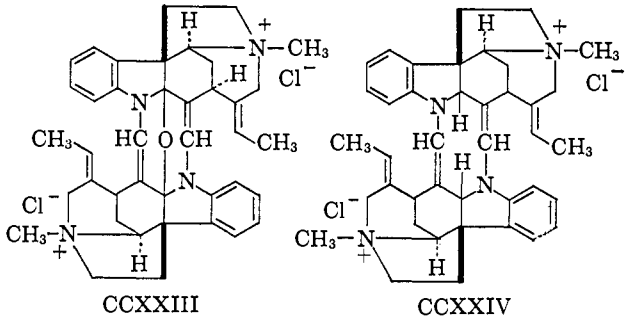
spectrum of akummicine. The quaternary nitrogen and hydrogen bonding are believed to play an important role in this effect.



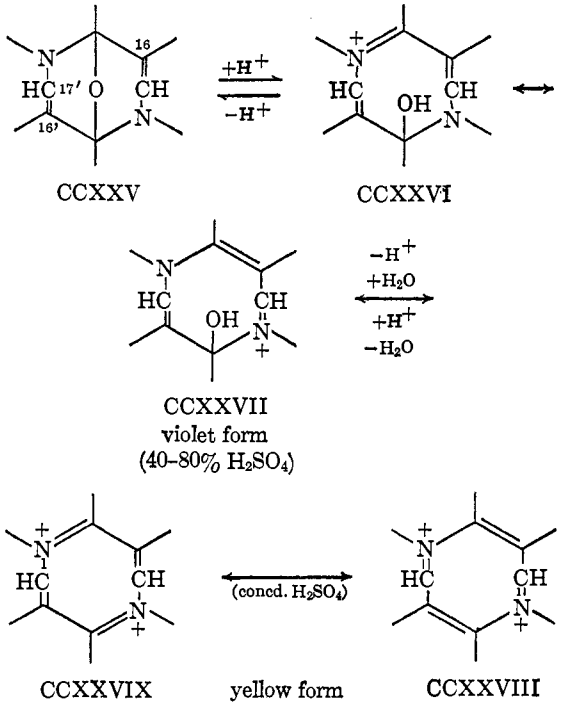
In alkali, C-fluorocurarine undergoes a reversible bathochromic shift, and this is due to the formation of the mesomeric anion CCXXII (42).

I. VINYLINDOLINES

Structurally and spectroscopically the vinylindoline group can be divided into the C-curarine type and the C-dihydrotoxiferine type. The ultraviolet spectrum of C-curarine dichloride (CCXXIII) (Figure 25) like alkaloids of this type show two definite maxima at ~264 and at 291–300 mμ. C-Dihydrotoxiferine dichloride (CCXXIV) (Figure 25) and similar alkaloids show only one band at ~290 mμ and a shoulder near 320 mμ. This proves useful in differentiating between both types of vinylindoline structures. The most likely explanation of this spectral difference is the fact that the central ring in C-curarine and similar structure is too rigid to allow full orbital overlap of the two enamine systems, and the spectrum is really only characteristic of CCXXV and does not represent the true vinylindoline chromophore (32).



The spectrum of C-curarine in 40–80% sulfuric acid undergoes a marked bathochromic shift especially of the 295-mμ band which is shifted to 550 mμ (log ε 4.0). In concentrated sulfuric acid, a yellow solution is formed. These color changes are best explained by the generation of mesomeric systems as indicated: CCXXV → CCXIX (240).

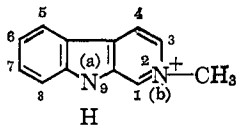


J. β-CARBOLINIUMS

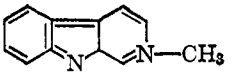
The β-carbolinium chromophore shows three distinct maxima (Table XXII), and the characteristic shape of the ultraviolet absorption curve of melinonine F (CCXXX, C_1 methyl) is seen in Figure 26.

Studies on partially hydrogenated pyridocolinium salts (171) and β-carboline degradative products from C-fluorocurine (31) illustrate the effect of alkali on this system. When N(a) (CCXXX) is substituted, sodium hydroxide has no apparent effect on the spectrum, but with N(a) as a secondary amine there is a bathochromic displacement of all three absorption maxima owing to the formation of the anhydro base (CCXXX–CCXXII).

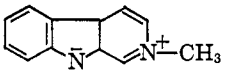
The alkaloids semperivirine (CCXXXIII), canthinone (CCXXXIV), 4-methylthiocarthinone, and tubo-



CCXXX

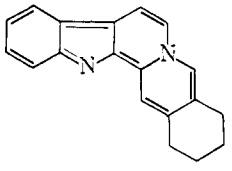


CCXXXI

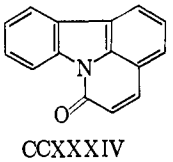


CCXXXII

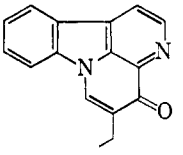
flavine (CCXXXV) (Figure 26) are included in this group to illustrate the effect on the ultraviolet spectrum of extending the carboline chromophore (Figure 26).



CCXXXIII

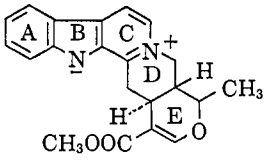


CCXXXIV

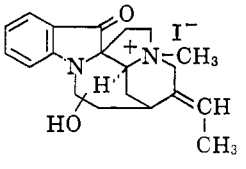


CCXXXV

The spectrum of tuboflavine shows very little change in 0.05 *N* methanolic potassium hydroxide, but in dilute acid bands with λ_{max} 277, 345 and 460 mμ (log ϵ 4.57, 4.01, and 3.52) were observed; this is quite similar to the spectrum of the methiodide in ethanol (λ_{max} 278, 340, and 455; log ϵ 4.57, 3.13, and 3.63) (218). Alstonine (CCXXXVI) and similar alkaloids with the OC=CCO$_2$Me system in ring E always show a selective absorption at 245 mμ which is masked by the absorption due to the indole or β-carboline nuclei.



CCXXXVI



CCXXXVII

Alkaloids with the *trans*-fused D/E ring junctions like ajmalicine and alstonine are more reactive than alkaloids with *cis* D/E ring junctions, and the ultraviolet spectra of *trans*-fused alkaloids only show relatively diffuse bands at 245 mμ (106, 250).

K. ψ-INDOXYLS

Fluorocurine (CCXXXVII) (Figure 27) and iboluteine are examples of the pseudoindoxyl chromophore. The ultraviolet spectrum is consistent with that of spiro(cyclopentane-1,2′-pseudoindoxyl) which has maxima at λ_{max} 235 and 400 (log ϵ 4.28 and 3.56) (346).

L. PYRIDOCARBAZOLES

Olivacine (CCXXXVIII) (Figure 27) and its isomer ellipticine display ultraviolet spectra characteristic of the pyridocarbazole chromophore. In acid, olivacine shows λ_{max} 242, 307, 351, and 412 mμ (log ϵ 4.45, 4.92, 3.78, and 3.59) (153). *u*-Alkaloid D (234) is quite

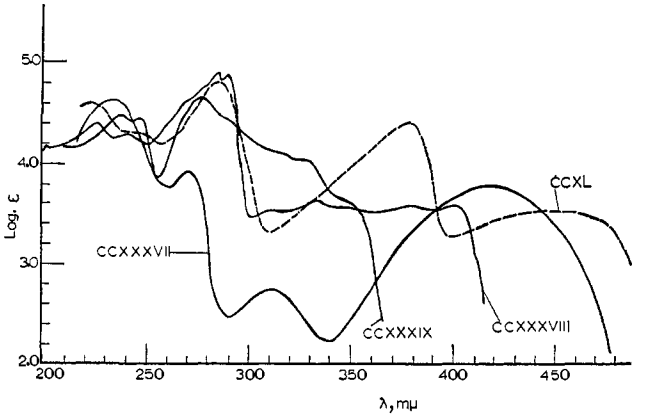
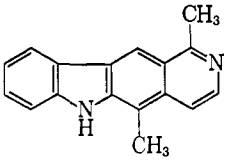


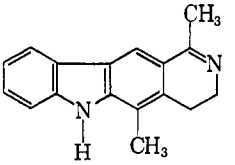
Figure 27.—Indoles and dihydroindoles: C-fluorocurine iodide (CCXXXVII) in water; olivacine (CCXXXVIII) in ethanol; 1,2-dihydroolivacine (CCXXXIX) in ethanol; cryptolepine (CCXL) methiodide in ethanol.

similar to 1,2-dihydro-10H-pyrido[4,3-*b*]carbazole and has the identical spectrum as 1,2-dihydroolivacine (CCXXXIX) (234) (Figure 27).

In 0.05 *N* potassium hydroxide in ethanol, ellipticine methiodide shows a bathochromic shift of all the maxima to λ_{max} 276, 338, 375, 400, and 520 mμ (log ϵ 4.46, 4.74, 3.92, 3.92, and 3.87) (159).

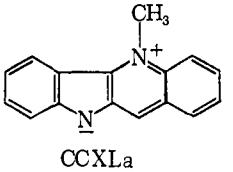


CCXXXVIII

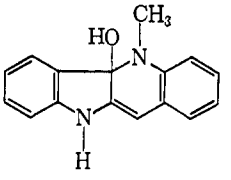


CCXXXIX

M. QUININDOLES



CCXLa



CCXLb

The methyl iodide of cryptolepine (CCXLa) shows bands at 275, 280, and 450 mμ (log ϵ 4.81, 4.40, and 3.52) and like ellipticine displays a bathochromic shift in 0.01 *N* potassium hydroxide of all the absorption bands, while in neutral solution the methyl iodide gives an ultraviolet spectrum as shown in Figure 27 (150). On evidence of the ultraviolet spectrum the alkaloid exists as in the anhydronium (CCXLa) rather than the pseudobase form (CCXLb) (268).

XVI. QUINAZOLINE AND QUINAZOLONE ALKALOIDS

One of the simplest alkaloids of this group, which is reviewed by Price (268), is vasicine (CCXLI). Vasicine shows a single maximum at 303 mμ (log ϵ 3.92) and in dilute hydrochloric acid displays a hypsochromic shift

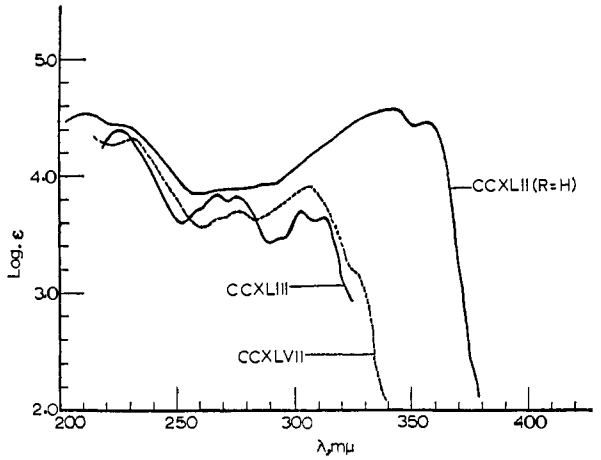
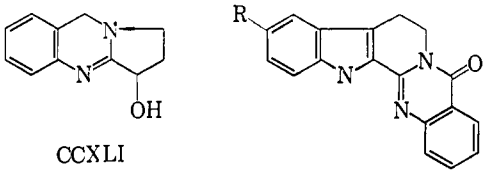


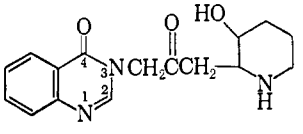
Figure 28.—Indoles and dihydroindoles: arborine (CCXLVII) in ethanol; rutaecarpine (CCXLII, R = H) in ethanol; febrifugine (CCXLIII) in ethanol.

to 284 mμ (log ε 3.51). Most of the other alkaloids in this group are 4-quinazolone derivatives and some compounds like rutaecarpine (CCXLII, R = H) (Figure 28) and hortiacine (CCXLII, R = OCH_3) also contain an indole nucleus.



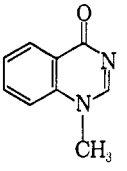
CCXLI

CCXLII

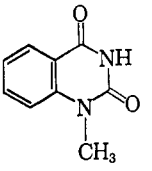


CCXLIII

The ultraviolet spectrum of febrifugine (CCXLIII) (Figure 28) shows a bathochromic shift in acid but not in alkali solution and so differs from 3-unsubstituted 4-quinazolones which show bathochromic shifts in both acid and basic solutions (216). Glycorine (CCXLIV) (1-methyl-4-quinazolone) has maxima at 269, 278, 306, and 317 mμ (183). In 0.01 *N* hydrochloric acid, the



CCXLIV

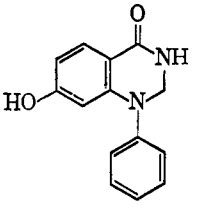


CCXLV

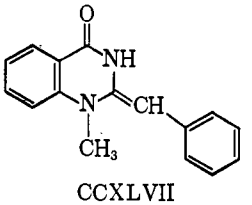
maxima shift to 282, 295, and 304 mμ (log ε 3.68, 3.73, and 3.69) (257). Glycosmicine (CCXLV) is unaltered in 0.01 *N* hydrochloric acid, but in 0.01 *N* sodium hydroxide the band at 244 mμ disappears and maxima appear at 223 and 313 mμ (log ε 4.70 and 3.75). This is characteristic of a diketo compound which is capable of existing in a keto–enol form (257).

It should be noted that quinazoline shows a hypsochromic shift of 45 mμ when it is converted into its cation (11).

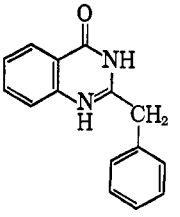
Aegelenine (CCXLVI), which has a N-phenyl substituent, shows three distinct maxima at 248, 278, and 328 mμ (log ε 4.03, 3.93, and 4.35) while arborine



CCXLVI



CCXLVII



CCXLVIII

TABLE XXIII

QUINAZOLINE AND QUINAZOLONE ALKALOIDS

Compound	λ_{max}, mμ	Log ε	Solvent[a]	Ref.
Aegelenine	248, 278, 328	4.03, 3.93, 4.35	E	88
Arborine	232, 277, 306	4.31, 3.69, 3.92	E	87
	(λ_{min} 260, 283)	(3.57, 3.62)		
Febrifugine and isofebrifugine	225, 266, 275, 302, 312	4.4, 3.84, 3.82, 3.68, 3.45	E	216
	(λ_{min} 250, 271, 288, 309)	3.62, 3.79, 3.43, 3.40		
Glycorine	269, 278, 306, 317	3.59, 3.66, 3.91, 3.84	E	257
	282, 295, 304	3.68, 3.73, 3.69	H^+ (0.01 *N*)	257
Glycosmicine	219, 244, 311	4.70, 3.97, 3.64	E	257
Glycosminine	225, 265, 303, 312	4.44, 3.95, 3.66, 3.57	E	257
Hortiacine[b]	218, 347	4.54, 4.56	E	249[c]
Hortiamine[b]	320, 376	4.17, 4.24	E	249
Rhetsinine	314	4.17	E	84
Rutaecarpine[b]	212, 231 sh, 328, 344, 358	4.53, 4.42, 4.50, 4.57, 4.48	E	249
	(λ_{min} 256–300, 350)	(3.86, 4.43)		
Vasicine (peganine)	303	3.92	E	311
Vasicine hydrochloride	284	3.51	E	311

[a] See footnote in Table I for key to solvents. [b] See footnote *gg* in Table XXII. [c] See footnote *a* in Table XXII.

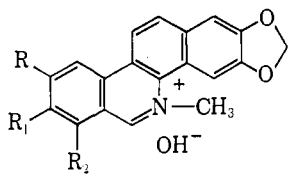
(CCXLVII) (Figure 28) has maxima at 232, 277, and 306 mμ (log ε 4.31, 3.69, and 3.92). It is of interest to compare the spectrum of arborine with that of glycosminine (CCXLVIII) which shows four maxima, 225, 265, 303, and 312 mμ (log ε 4.44, 3.95, 3.66, and 3.57), and to note that the values of the latter are closer to those of 4-hydroxyquinazoline than those of 1-methyl-4-quinazolone (257) (see Table XXIII).

XVII. BENZOPHENANTHRIDINE GROUP

The ultraviolet spectra of the benzophenanthridine or α-naphthaphenanthridine alkaloids and their key transformation products are best divided into five sections: (A) benzophenanthridines, (B) dihydrobenzophenanthridines, (C) oxybenzophenanthridines, (D) hexahydrobenzophenanthridine derivatives, and (E) oxyhexahydrobenzophenanthridines.

A. BENZOPHENANTHRIDINES

Members of this group are chelerythrine (CCXLIX, R = H; $R_1 = R_2 = OCH_3$), sanguinarine (CCXLIX, R = H; $R_1 + R_2 = CH_2O_2$), avicine (CCXLIX, $R + R_1 = CH_2O_2$; R_2 = H), and nitidine (CCXLIX, $R = R_1 = OCH_3$; R_2 = H).



CCXLIX

The complex spectrum of the N-nor compound is exemplified by norchelerythine (Figure 29) which shows bands at 215, 243, 256, 277, 324, and 384 mμ (log ε 4.24, 4.58, 4.57, 4.71, 4.16, and 3.47). This is a substituted benzenoid extension of the phenanthridine spectrum which shows bands at 250 (log ε 4.65), 295 (3.76), 346 (3.29), and at 450 mμ (1.85) (238). Spectral values for the unsubstituted benzophenanthridine molecule are given in Table XXIV.

Chelerythrine, sanguinarine, avicine, and nitidine are isolated as quarternary salts, and on being basified undergo a disproportionation reaction to give dihydrobenzophenanthridines and oxybenzophenanthridines.

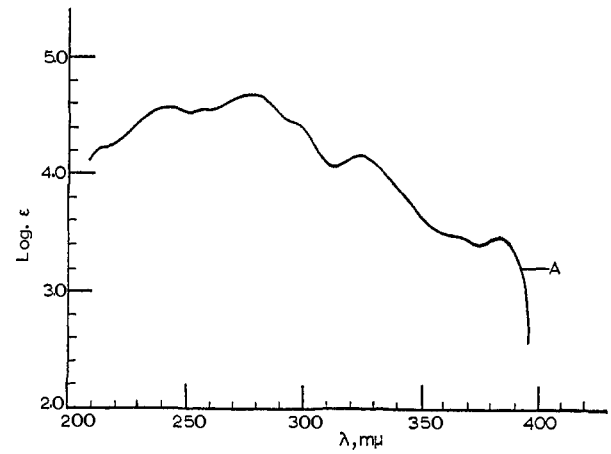
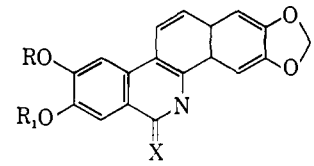


Figure 29.—Benzophenanthridine group: (A) N-norchelerythrine (see chelerythrine (CCXLIX)) in ethanol.

B. DIHYDROBENZOPHENANTHRIDINES

One product derived from the treatment of benzophenanthridines with ammonium hydroxide is a dihydrobenzophenanthridine derivative which has an absorption spectrum showing three bands, 228–232, 278, and 311–322 mμ. Dihydroavicine (CCL, $R + R_1 = CH_2$; X = H_2) and dihydronitidine (CCL, $R = R_1 = CH_3$; X = H_2) exemplify this group.



CCL

C. OXYBENZOPHENANTHRIDINES

The other product from alkali treatment of benzophenanthridine is the oxybenzophenanthridine derivative, for example, oxyavicine (CCL, $R + R_1 = CH_2$; X = O) and oxynitidine (CCL, $R = R_1 = CH_3$; X = O), and characteristic absorption bands are shown in Table XXIV.

TABLE XXIV

BENZOPHENANTHRIDINE GROUP

Compound	λ_{max}, mμ	Log ε	Solvent[a]	Ref.
Benzophenanthridine	237, 256, 262, 284 sh, 306, 343, 359	4.48, 4.78, 4.88, 4.31, 3.88, 3.63, 3.69	E	20
Norchelerythine	215, 243, 256, 277, 324, 384	4.24, 4.58, 4.57, 4.71, 4.16, 3.47	E	21
	(λ_{min} 220, 250, 260, 313, 373)	(4.22, 4.54, 4.58, 4.10, 3.42)		
Dihydroavicine	232, 278, 322	4.60, 4.50, 4.33	E	136
Dihydronitidine	228, 278, 311	4.61, 4.54, 4.29	E	13a
Oxyavicine	248, 278, 284, 322, 332	4.50, 4.70, 4.76, 4.21, 4.19	E	13b
Oxynitidine	251, 277, 288, 320, 333, 367	4.59, 4.72, 4.81, 4.20, 4.18, 3.63	E	13a

[a] E = ethanol (95%–absolute).

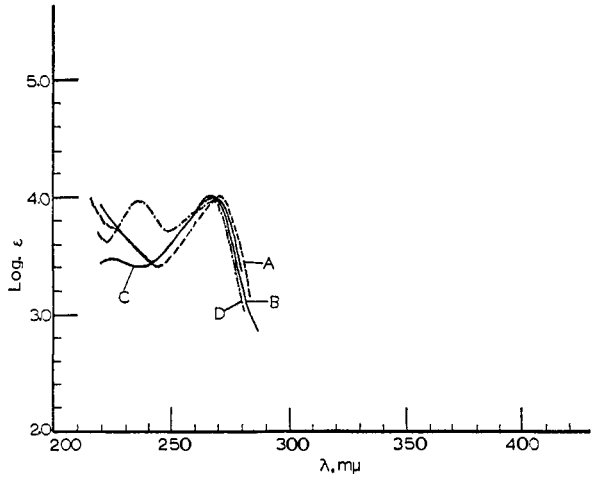
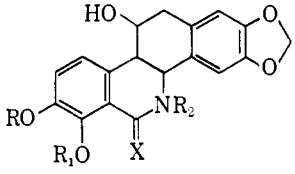


Figure 30.—Xanthines: (A) caffeine (CCLII, R = R_1 = R_2 = CH_3) in buffer at pH 2–12; (B) 7-methylxanthine (CCLII, R = R_1 = H, R_2 = CH_3) in buffer at pH 6; (C) xanthine (CCLII, R = R_1 = R_2 = H) in buffer at pH 5; (D) isocaffeine (CCLIII, R = R_1 = R_2 = CH_3) in buffer at pH 6.

D. HEXAHYDROBENZOPHENANTHRIDINES

Chelidonine (CCLI, R + R_1 = CH_2; R_2 = CH_3: X = H_2), norchelidonine (CCLI, R + R_1 = CH_2;



CCLI

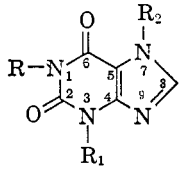
R_2 = H; X = H_2), and α-homochelidonine (CCLI, R = R_1 = R_2 = CH_3; X = H_2) are members of this group, and the ultraviolet spectrum should be that of a simple benzenoid system.

E. OXYHEXAHYDROBENZOPHENANTHRIDINES

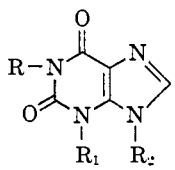
Oxychelidonine (CCLI, R + R_1 = CH_2; R_2 = CH_3; X = O) is the only representative so far known in this group, and the ultraviolet spectrum has not been reported.

XVIII. PURINE GROUP

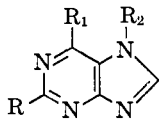
The purine bases are of great biochemical interest because they are one of the major components of the nucleic acids. Only a few of these bases have been regarded as alkaloids in the classical sense. Many of these bases occur, however, in plants as well as in animals and are worthy of consideration. The ultraviolet spectra have been of great importance in the determination of the structures of these bases. The main structural types are (A) xanthine and isoxanthine derivatives (CCLII and CCLIII), and (B) purine derivatives and purine betaines (CCLIV and CCLV).



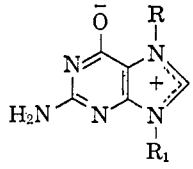
CCLII



CCLIII



CCLIV

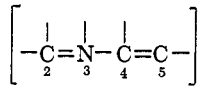


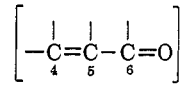
CCLV

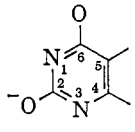
A. XANTHINE DERIVATIVES

Xanthine derivatives (CCLII and CCLIII) occur as the well-known alkaloids caffeine (1,3,7-trimethylxanthine), theobromine (3,7-dimethylxanthine), theophylline (1,3-dimethylxanthine), and heteroxanthine (7-methylxanthine). There has been a good deal of study of the effect of substitution on the ultraviolet spectra.

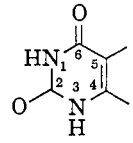
It has been postulated (79) that the spectra of xanthine derivatives are essentially due to the chromophore of the pyrimidine ring (CCLVIa or CCLVIb) and that the imidazole portion of the purine molecule makes little contribution. The 7- and 9-substituted xanthines







CCLVIa



CCLVIb

(CCLII and CCLIII) show, however, spectral differences in neutral or acidic solution which can be used to differentiate between the two types.

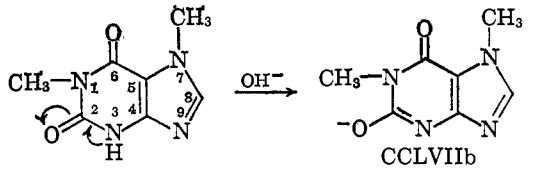
The following generalizations can be made about the ultraviolet spectra of the xanthines.

(a) 9-Substituted xanthines, *e.g.*, 9-methyl-, 3,9-dimethyl-, and 1,3,9-trimethylxanthines, show two bands of about equal intensity in neutral or acid solution at ~235 (log ε 4.0) and ~266 mμ (4.0). The other types (*e.g.*, xanthine, 1-, 3-, and 7-methyl-, 1,3-, 1,7-, and 3,7-dimethyl-, and 1,3,7-trimethylxanthines show one main band at ~265–270 mμ and sometimes a weaker band or shoulder at 225 mμ. Thus the spectrum of caffeine (CCLII, R = R_1 = R_2 = CH_3) can be readily distinguished from isocaffeine (CCLIII, R = R_1 = R_2 = CH_3) (*cf.* Figure 30).

(b) The spectra of the monoanions of xanthines are also different. In alkaline solution (pH 9–12) the 3- and/or 7-substituted xanthines show one main band at ~275–290 mμ (log ε 4.0) and sometimes a weaker band

or shoulder at 230–245 mμ (log ε 3.7). Xanthine and the 1- and/or 9-substituted xanthines (*e.g.*, 1- and 9-methyl, 1,9-dimethyl-, and 1,3,9-trimethylxanthines) show two bands of approximately equal intensity at 242 (log ε 3.9) and 275 mμ (4.1) (Figure 31).

(c) Xanthines with the 3-position free show different spectra in alkaline solution from the 3-substituted xanthines. The 3-substituted xanthines show a slight bathochromic and hyperchromic effect in alkali. The spectra of the 3-unsubstituted xanthines show a significant bathochromic shift in alkali (81) due to transitions of the type CCLVIIa → CCLVIIb. The sequence of



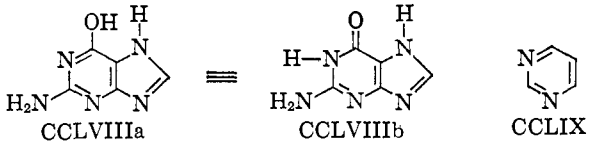
CCLVIIa CCLVIIb

ionization in the xanthines has been determined by examination of the spectra of a series of compounds at different pH values. It was concluded that the uncharged xanthines occur principally as the carbonyl form and that the ionization takes place in the order N-3, N-2, N-1 (81). Ultraviolet spectra showed (262) that in the neutral molecule, the labile hydrogen on the imidazole ring was located on N-7, and in monoanions on N-9. The spectra of a number of substituted xanthines are summarized in Table XXV.

B. PURINES

Purine derivatives occur in plants and also in the nucleoproteins of living cells. Alkaline hydrolysis of the nucleic acid gives the purine bases, a sugar residue, and phosphoric acid. Ultraviolet spectra have been of great assistance in determining the substitution pattern in the purine molecule. All the purines show strong absorption in the region 250–290 mμ. Purine itself (CCLIV, R = R_1 = R_2 = H) shows bands below 220 mμ and at 263 mμ. Auxochromes such as OH and NH_2 shift the short wave length band above 220 mμ (237).

A large number of substituted guanines (2-amino-6-hydroxypurine derivatives (CCLVIIIa or CCLVIIIb) have been studied, and the dissociation sequence of the acid hydrogen atoms was established as N-1 then N-7 (261). A comparison of the ultraviolet spectra of pyrimidine (CCLIX) derivatives and purine (CCLIV) derivatives show basic similarities. It was concluded that the imidazole ring makes little contribution to the ultraviolet spectra of purine and that the major chromophore is the pyrimidine ring system –C=C–C=N–



CCLVIIIa CCLVIIIb CCLIX

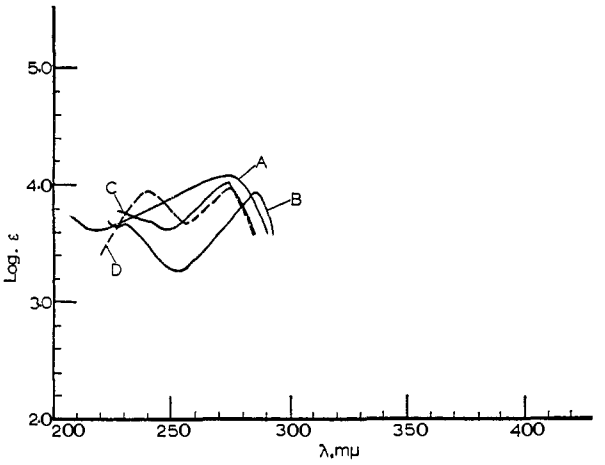
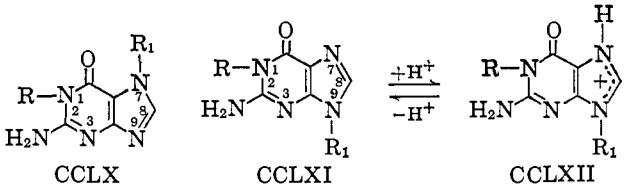


Figure 31.—Xanthines: (A) 1,3-dimethylxanthine (CCLII, R = R_1 = CH_3; R_2 = H) in buffer at pH 10.8; (B) 7-methylxanthine (CCLII, R = R_1 = H; R_2 = CH_3) in buffer at pH 11; (C) 3,7-dimethylxanthine (CCLII, R = H; R_1 = R_2 = CH_3) in buffer at pH 10; (D) xanthine (CCLII, R = R_1 = R_2 = H) in buffer at pH 10.

(80). The spectra of the neutral molecules of 1-, or 7-, or 9-methyl-substituted guanines (CCLX and CCLXI) are different, the 1- and 7-substituted having two bands and the 9-substituted having one band and a



CCLX CCLXI CCLXII

shoulder (Figure 32).

The 9-methyl-substituted guanines show a bathochromic shift on protonation owing to the transition CCLXI → CCLXII.

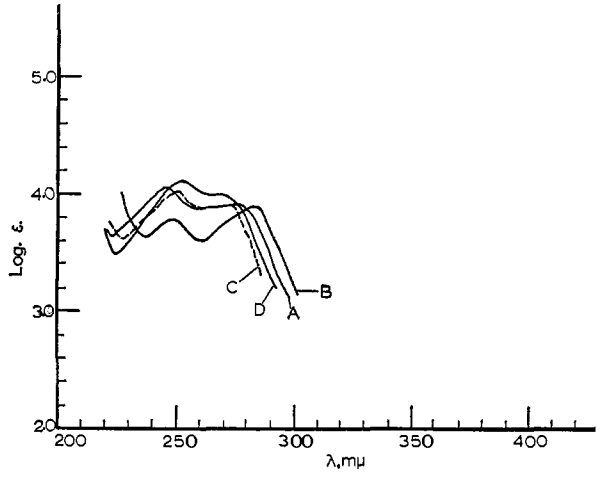


Figure 32.—Purines: (A) guanine (CCLX, R = R_1 = H) in buffer at pH 6; (B) 7-methylguanine (CCLX, R = H, R_1 = CH_3) in buffer at pH 6; (C) 1-methylguanine (CCLX, R = CH_3, R_1 = H) in buffer at pH 6; (D) 9-methylguanine (CCLXI, R = H, R_1 = CH_3).

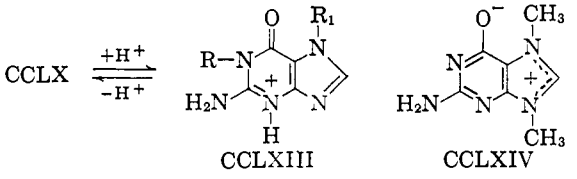
TABLE XXV

XANTHINES AND PURINES

Compound	$\lambda_{max.}$ mμ	Log ε	$\lambda_{min.}$ mμ	Log ε	Solvent	Molecular species[a]	Ref.
Xanthines							
Xanthine	225, 266	3.49, 4.03	239	3.42	pH 5	0	262
	241, 276	3.95, 3.97	257	3.69	pH 10	−	262
	242 sh, 283	3.65, 3.97	257	3.61	pH 14.0	=	262
1-Methylxanthine	225, 267	3.52, 4.04	239	3.48	pH 5	0	174, 262,
	242, 276	3.93, 3.98	258	3.79	pH 10	−	174, 262
	242 sh, 283	3.69, 4.00	...	...	pH 14	=	262
	225 sh, 271	3.66, 4.00	...	...	pH 5	0	174
3-Methylxanthine	274	4.10	...	...	pH 10	−	174, 262
	232 sh, 274	3.77, 4.12	...	...	pH 14.0	=	262
7-Methylxanthine (heteroxanthine)	268	4.01	241	3.46	pH 6	0	174, 262
	231, 287	3.68, 3.93	227, 253	3.66, 3.26	pH 11	−	174, 262
9-Methylxanthine	235, 264	3.86, 3.97	218, 247	3.57, 3.75	pH 5	0	174
	247, 278	3.97, 3.97	225, 263	3.43, 3.75	pH 10	−	174, 262
1,3-Dimethylxanthine (theophylline)	272	4.02	243	3.43	pH 6.7	0	81, 262
	276	4.08	246	3.61	pH 10.8	−	81, 262
1,7-Dimethylxanthine	269	4.01	242	3.53	pH 6	0	81, 262
	289	3.95	257	3.37	pH 10.6	−	81
1,9-Dimethylxanthine	238, 263	3.82, 3.98	...	...	pH 3	0	262
	248, 276	3.94, 3.95	261	3.8	pH 9.0	−	262
3,7-Dimethylxanthine (theobromine)	271	4.01	243	3.45	pH 7	0	81, 262
	234 sh, 274	3.72, 4.02	250	3.62	pH 10	−	81
	234, 273	3.85, 4.01	253	3.64	pH 13	=	81, 262
3,9-Dimethylxanthine	235, 268	3.91, 3.99	253	3.75	pH 7.0	0	262
	240 sh, 269	3.82, 4.01	...	...	pH 13.0	−	262
1,3,7-Trimethylxanthine (caffeine)	227 sh, 272	3.74, 4.02	245	3.42	pH 2–12	0	81, 174, 262
1,3,9-Trimethylxanthine (isocaffeine)	237, 268	3.99, 4.00	223, 250	3.64, 3.73	pH 6	0	174, 262
Purines							
Purine	<220, 260	>4.09, 3.79	...	...	pH 0.3	+	237
	<220, 263	>3.48, 3.90	...	...	pH 5.7	0	237
	219, 271	3.92, 3.88	...	...	pH 11.0	−	237
Guanine	248, 270 sh	4.06, 3.86	...	...	pH 0	+	261
	245, 274	4.04, 3.92	222, 260	3.64, 3.86	pH 6	0	261
	243, 273	3.93, 4.00	235, 257	3.90, 3.88	pH 11	−	261
	273	3.98	...	...	pH 14	=	261
1-Methylguanine	250, 270 sh	4.03, 3.85	...	...	pH 0	+	261
	249, 273	4.01, 3.91	227, 264	3.61, 3.87	pH 6	0	261
	262 sh, 277	3.90, 3.96	239	3.69	pH 13	−	261
7-Methylguanine	250, 270 sh	4.04, 3.85	...	...	pH 0	+	261
	248, 283	3.79, 3.89	236, 260	3.74, 3.59	pH 6	0	261
	240 sh, 280	3.81, 3.89	254	3.58	pH 13	−	261
9-Methylguanine	251, 276	4.08, 3.88	...	...	pH 0	+	261
	252, 270 sh	4.10, 3.97	224	3.48	pH 6.0	0	261
	258 sh, 268	4.01, 4.05	...	...	pH 13	−	261
1,7-Dimethylguanine	252, 273 sh	4.01, 3.83	...	...	pH 0	+	261
	250, 283	3.75, 3.87	237, 260	3.72, 3.61	pH 6.0	0	261
1,9-Dimethylguanine	254, 279 sh	4.05, 3.88	...	...	pH 0	+	261
	255, 269 sh	4.09, 4.00	288	3.43	pH 6	0	261
7,9-Dimethyl-2-amino-6-oxodihydropurinium betaine (herbipoline)	253, 279	4.07, 3.88	...	...	pH 4	+	261
	252, 282	3.77, 3.92	...	...	pH 9.5	±	261
1,7-Trimethyl-2-amino-6-oxodihydropurinium cation	254, 280	4.05, 3.89	...	...	pH 5.0	+	261

[a] Neutral molecule, 0; monoanion, −; dianion, =; monocation, +; zwitterion, ±.

The long wave length band of the 1- or 7-substituted guanines show a hypsochromic shift associated with the transition CCLX to CCLXIII. The spectra of the monoanions of the guanines are similar with maxima at ~275 mμ (log ε 3.9) (Figure 33).



Herbipoline, a base isolated from the siliceous sponge *Geogia gigas*, has been assigned structure CCLXIV (7,9-dimethyl-2-amino-6-oxodihydropurinium betaine) on the basis of the ultraviolet spectral evidence (261). The ultraviolet spectral data of a number of purine derivatives are summarized in Table XXV.

XIX. MISCELLANEOUS ALKALOIDS

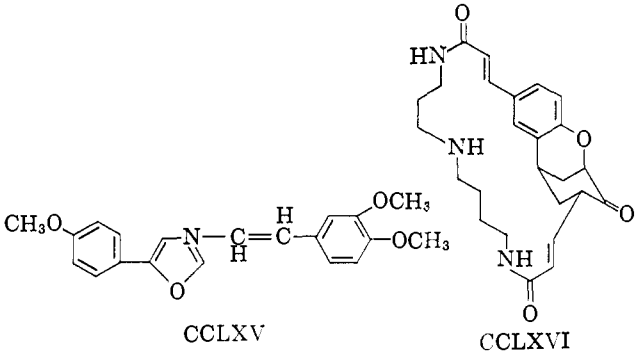
There are several alkaloids which are conveniently discussed in this group. Most of these alkaloids have been characterized fairly recently and do not conveniently fall into any of the classes previously discussed.

A. ANNULOLINE

Annuloline (CCLXV) has a maximum almost in the visible (354 mμ, log ε 4.48) and this is due to the extended chromophoric system present, which like N-methylhalfordium chloride (LXIII) also contains an oxazole ring.

B. LUNARINE

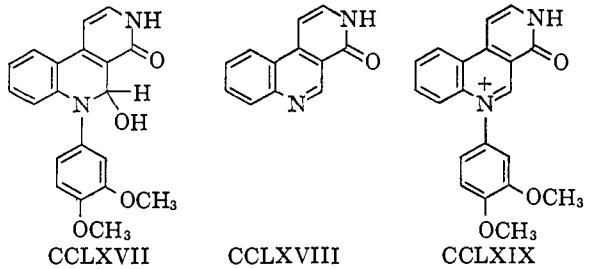
Lunarine (CCLXVI) has a spectrum with maxima at 208, 224, 296, and 314 mμ (log ε 4.46, 4.41, 4.34, and 4.23). In 0.1 *N* sodium hydroxide, there are maxima at 224 and 355 mμ (log ε 4.39 and 4.43), and in 10 *N* hydrochloric acid, there is a similar bathochromic shift to give bands at 236 and 354 mμ (log ε 4.2 and 4.38) (264).



CCLXV CCLXVI

C. PERLOLINE

The alkaloid perloline, whose structure has recently been determined by X-ray methods, represents the first example of a natural product with the diazaphenanthrene ring system (201). The spectra of perloline



CCLXVII CCLXVIII CCLXIX

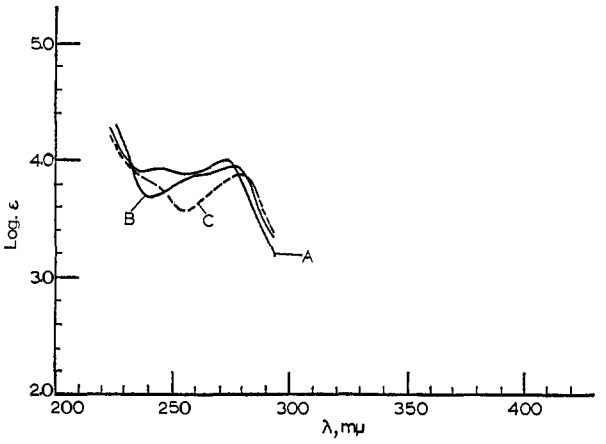


Figure 33.—Purines: (A) guanine (CCLX, R = R_1 = H) in buffer at pH 11; (B) 1-methylguanine (CCLX, R = CH_3; R_1 = H) in buffer at pH 13; (C) 7-methylguanine (CCLX, R = H, R_1 = CH_3) in buffer at pH 13.

(CCLXVII), methyl perloline, and perlolidine (CCLXVIII), the oxidation product of perloline, are similar in acid solution with maxima at 235–260 (log ε ~4.3) and 380–400 mμ (~4.1). Perloline (CCLXVII) exists in two forms in water: as the free base and the positive charged ion.

The perloline salts have the structure CCLXIX (the protonated form of anhydroperloline).

The spectra of perloline solutions in 2-propanol–water mixtures have been studied, and the bathochromic shifts observed in 2-propanol solutions have been attributed to the replacement of constitutional water in perloline by 2-propanol (240), though it is not clear how this replacement should affect the ultraviolet chromophore. The spectra of perlolidine, which also occurs naturally, in neutral or alkaline solution are similar, but in acid solution the bathochromic shift observed is consistent with the quinoline ring system. Spectral data are summarized in Table XXVI and Figure 34.

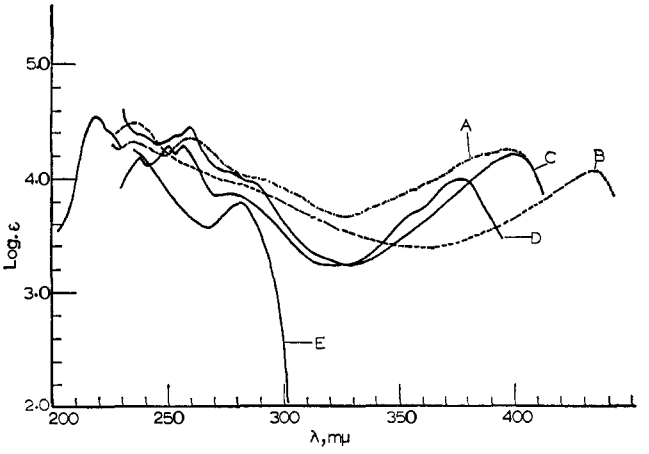


Figure 34.—Miscellaneous alkaloids: (A) perloline (CCLXVII) in 0.01 *N* acid; (B) perloline in 0.01 *N* alkali; (C) methylperloline in 0.01 *N* acid; (D) perlolidine (CCLXVIII) in 0.01 *N* acid: (E) protostephanine (CCLXX) in methanol.

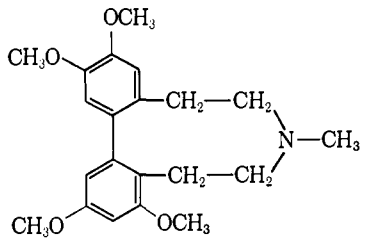
TABLE XXVI
MISCELLANEOUS ALKALOIDS

Compound	λ_{max}, mμ	Log ε	λ_{min}, mμ	Log ε	Solvent[a]	Ref.
Annuloline	354	4.48	285	3.85	Cy	17
Lunarine	208, 224, 296, 315	4.46, 4.41, 4.34, 4.23	...	...	E	264
	224, 355	4.39, 4.43	...	...	OH^- (0.1 N)	
	236, 354	4.20, 4.38	...	...	H^+ (0.1 N)	
Methyl perloline[b]	238 sh, 256 sh	4.39, 4.38	247	4.30	H^+ (0.01 N)	240
	259, 273 sh	4.44, 4.08	327	3.26		
	286 sh, 388 sh, 402	3.98, 4.11, 4.22	...	...		
	240 sh, 246 sh	4.53, 4.37	266	4.14	OH^- (0.01 N)	240
	250 sh, 280	4.24, 4.15	346	3.72		
	306 sh, 320 sh, 375	3.84, 3.79, 3.88	...	...		
Perlolidine[c]	237 sh, 240 sh	4.36, 4.13	216	3.69	B, pH 7	240
	244, 249 sh	4.43, 4.40	289	3.42		
	323, 336	3.73, 3.80	327	3.66		
	352	3.85	342	3.66		
	238, 249	4.18, 4.24	241	4.11	H^+ (0.01 N)	240
	256, 273	4.29, 3.87	251	4.22		
	280 sh, 352 sh	3.83, 3.65	270	3.85		
	378	3.99	313–325	3.25		
	233 sh, 238	4.37, 4.43	296	3.37	OH^- (0.01 N)	240
	282 sh, 328 sh	3.77, 3.70	...	...		
	360	3.84	...	...		
Perloline[d]	234, 259, 280 sh, 384 sh, 399	4.32, 4.37, 4.06, 4.21, 4.24	288, 248, 327	4.27, 4.20, 3.66	H^+ (0.01 N)	240
	235, 258 sh, 280 sh, 434	4.49, 4.12, 3.96, 4.19	360	3.39	OH^- (0.01 N)	240
Protostephanine	220, 281	4.55, 3.79	268	3.6	M	325
Nitrogen-free product from protostephanine	218, 284	4.49, 3.84	260	3.38	M	325
Streptolydigin acetate	329	4.47	...	...	?	284
Thiobinupharidine	298	3.04	...	...	E	1
Virosecurinine	256	4.26	...	...	E	246

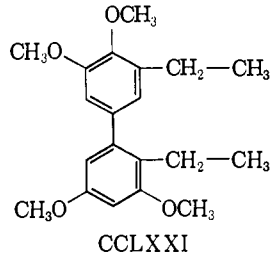
[a] See footnote in Table I for key to solvents. [b] Log ε values calculated from absorptivity values using a molecular formula of $C_{21}H_{20}N_2O_4$. [c] Log ε values calculated from absorptivity values using a molecular formula of $C_{12}H_8N_2O$. [d] Log ε values calculated from absorptivity values using molecular formula of $C_{20}H_{18}N_2O_4$.

D. PROTOSTEPHANINE

Protostephanine (CCLXX), a Menispermacae alkaloid, is a substituted biphenyl (325). The spectrum shows maxima at 220 (log ε 4.55) and 281 mμ (3.79)



CCLXX



CCLXXI

(Figure 34). The tetrahydro, nitrogen-free substituted biphenyl degradation product (CCLXXI) has a similar spectrum typical of biphenyls (62).

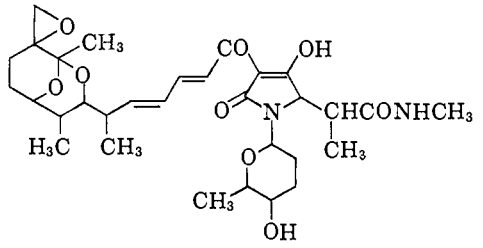
E. STREPTOLYDIGIN

The effect of pH on the complex spectrum of the antibiotic alkaloid streptolydigin (CCLXXII) has been studied (119) and good correlations between different hydrogenation products and their ultraviolet spectra have been obtained (284). Conversion of streptolydigin to the enol acetate gives a spectrum with a single maximum at 329 mμ (log ε 4.47). This is in accord with a trienone RCH=C(CH_3)CH=CHC=C(OAc)C=O.

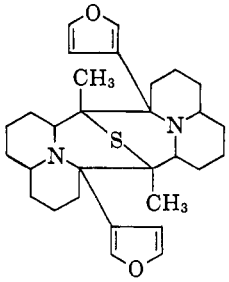
F. THIOBINUPHARIDINE

Thiobinupharidine, isolated from *Nuphar luteum*, has been assigned structure CCLXXIII (1), which classes it with the small group of sulfur-containing alkaloids. Thiobinupharidine could be regarded as a

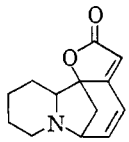
special type of quinolizidine alkaloid, and the maximum at 198 mμ (log ε 3.04) is in agreement with the isolated furan rings.



CCLXXII



CCLXXIII



CCLXXIV

G. VIROSECURININE

Virosecurinine (CCLXXIV) (246) is the optical enantiomorph of securinine (291, 263a). The alkaloid, which can be regarded as a pyrrocoline derivative has a maximum at 256 mμ (log ε 4.27). This is consistent with a conjugated unsaturated lactone.

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