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CIRCULAR DICHROISM STUDIES OF DIMERIC FUNGAL PIGMENTS, (-)-LUTEOSKYRIN AND (+)-RUGULOSIN.

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The c.d. curves of (-)-luteoskyrin and (+)-rugulosin, as calculated on the basis of an electric dipole-electric dipole coupling mechanism, the Aromatic Chirality Method, are in good agreement with experimental curves; the method is thus applicable to complex systems without ambiguity and in an extremely facile manner.

The split type Cotton effects characteristic of a dipole-dipole coupling mechanism have been extensively applied to the determination of absolute configurations of various natural products.1-9) The same phenomena have been observed for fungal pigments, (-)-luteoskyrin from *Penicillium islandicum* Sopp, and (+)-rugulosin from *Penicillium rugulosum* Thom;10) the agreement in absolute configurations deduced from these exciton split c.d. curves with X-ray crystallographic results, and the similality between the observed and calculated c.d. curves of (-)-luteoskyrin provides an excellent proof for the validity of the "Aromatic Chirality Method".4-9)

The structures10) and absolute configurations11) of the two pigments (Figs. 1 and 2) have been established by chemical reactions, spectroscopy,10) and by X-ray analyses.11) As these dimeric pigments have two identical π-electron chromophores separated by rigid σ-skeletons, it was expected that the chirality of the two π-electron chromophores, i.e., absolute configurations of the pigments could be determined by the signs of split type Cotton effects arising from electric dipole-electric dipole interactions.

The symmetrical basic chromophore of these pigments is 2,3-dihydro-1,4-naphtoquinone, which exhibits three $\pi\rightarrow\pi^*$ transition uv bands. Polarizations of these transitions were calculated by the Pariser-Parr-Pople method; they are polarized along long (z), short (y), long (z) axes, respectively (Table 1). The same polarization order is also found in 2,3-dihydronaphthazarin, the symmetrical basic chromophore of (-)-luteoskyrin (Table 1). Uv spectra of (-)-luteoskyrin and (+)-rugulosin exhibit approximately three bands, and in accordance c.d. spectra show six split type Cotton effects corresponding to the three transitions (Figs. 1 and 2). Signs of split type Cotton effects (- + / + - / - + from longer wave-

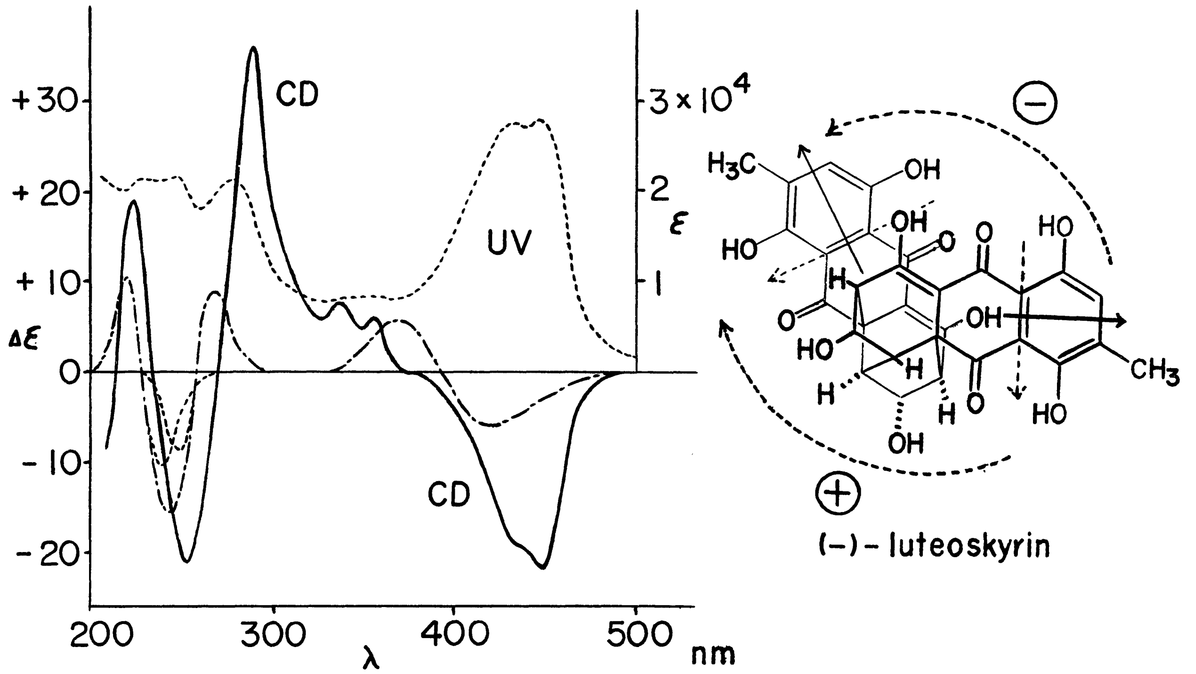


Figure 1. C.d. (——) and u.v. (------) spectra of (-)-luteoskyrin in ethanol and calculated c.d. curve (—·—) using the u.v. data of 2,3-dihydronaphthazarin; around 245 nm, two negative Cotton effects (-----) overlap to give one peak.

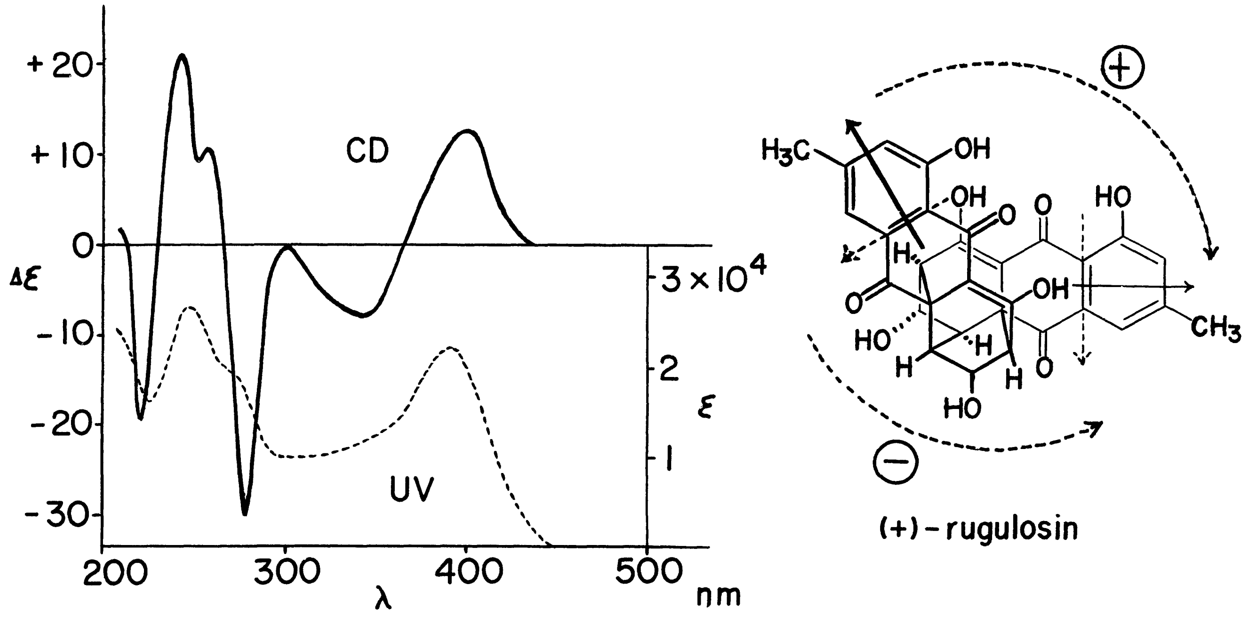
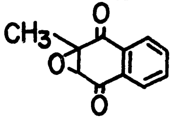
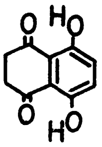


Figure 2. C.d. (——) and u.v. (-----) spectra of (+)-rugulosin in ethanol.

Table 1. Transition Energies, Oscillator Strengthes, and Polarizations of 2,3-Dihydro-1,4-naphthoquinone and 2,3-Dihydronaphthazarin Chromophores.

Compound	Obsd.1)		Calcd.		
	E (eV)	f	E (eV)	f	polarization
Vitamin K_1 oxide 	4.07	0.025	4.20	0.097	z-axis
	4.66	0.105	4,65	0.590	y-axis
	5.46	0.664	5.45	0.805	z-axis
2,3-Dihydronaphthazarin 	3.15	0.128	3.39	0.333	z-axis
	4.82	0.186	4.49 5.03	0.260 0.315	y-axis
	5.44	0.195	5.54	0.299	z-axis

1) U.v. spectra were measured in ethanol. 2) Y- and z-axes were defined as follows:

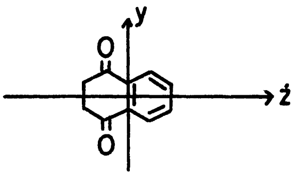


Table 2. The Approximate Calculation of Split Type Cotton Effects of (-)-Luteoskyrin using the U.v. Data of 2,3-Dihydronaphthazarin.

Wave Number $\sigma(cm^{-1})$	Rotational Strength R (cgs. unit)	1/e-Width $\Delta\sigma(cm^{-1})$	$\Delta\varepsilon_{max}$	$\Delta\varepsilon_{apparent}(nm)$
25125.6	91.0×10^{-40}	2309.5	-24.7	- 5.9(420)
25773.2			+24.7	+ 5.9(369)
38610.0	94.5×10^{-40}	2080.1	+43.4	+ 8.9(267)
39215.7			-43.4	- 8.9(248)
43668.1	138.4×10^{-40}	2598.0	-57.4	-10.8(238)
44052.9			+57.4	+10.8(219)

length) of (-)-luteoskyrin indicate that the chirality between the two long axes is positive and this clearly leads to the absolute configuration depicted in Fig.1. The result is in accordance with that of X-ray analysis. In the case of (+)-rugulosin, similar split type Cotton effects were observed, but the signs are opposite (+ - / - + / + - from longer wavelength) to those of (-)-luteoskyrin (Fig. 2). Accordingly the absolute configuration of (+)-rugulosin is the mirror image of that of (-)-luteoskyrin.

An approximate calculation of the c.d. curve7) of (-)-luteoskyrin using the u.v. data of 2,3-dihydronaphthazarin also supported these conclusions. The rotational strength due to an electric dipole-electric dipole coupling term

$$R_{ao} = \mp (1/2)\pi\sigma_a \vec{R}_{ij}\cdot(\vec{\mu}_{ioa} \times \vec{\mu}_{joa})$$

can be estimated from the u.v. peak position, geometry of molecule,$^{12)}$ and oscillator strength of the transition; location of the point dipole was assumed to be at the cross-point of the y and z axes (see footnote figure, Table 1). If a c.d. Cotton effect is approximated by a Gaussian curve, the value of $\Delta\varepsilon_{max}$ can be obtained from the following equation

$$R_{ao} = 2.295 \times 10^{-39}\sqrt{\pi}\Delta\varepsilon_{max}\cdot\Delta\sigma/\sigma_{max}$$

where the 1/e width, $\Delta\sigma$, is estimated from the u.v. spectra of 2,3-dihydronaphthazarin. The resulting Cotton effects are illustrated in Fig. 1; around 245 nm, two negative Cotton effects overlap to give one apparent peak. In (+)-rugulosin, these two Cotton effects are clearly observed (Fig. 2). The satisfactory agreement between observed and calculated c.d. curves demonstrate that the Aromatic Chirality Method is applicable to complex chromophores simply if the directions of transitions are known.

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References

1) N. Harada and K. Nakanishi, *J. Amer. Chem. Soc.*, **91**, 3989 (1969).
2) N. Harada, H. Sato, and K. Nakanishi, *Chem. Commun.*, 1691 (1970).
3) N. Harada and K. Nakanishi, *Chem. Commun.*, 310 (1970).
4) N. Harada, K. Nakanishi, and S. Tatsuoka, *J. Amer. Chem. Soc.*, **91**, 5896 (1969).
5) S. Marumo, N. Harada, K. Nakanishi, and T. Nishida, *Chem. Commun.*, 1693 (1970).
6) T. Ito, N. Harada, and K. Nakanishi, *Agr. Biol. Chem. (Japan)*, **35**, 797 (1971).
7) N. Harada, S. Suzuki, H. Uda, and K. Nakanishi, *J. Amer. Chem. Soc.*, **93**, in press (1971).
8) S.F. Mason and G.W. Vane, *J. Chem. Soc. (B)*, 370 (1966).
9) S.F. Mason, K. Schofield, R.J. Wells, J.S. Whitehurst, and G.W. Vane, *Tetrahedron Letters*, 137 (1967).
10) U. Sankawa, S. Seo, N. Kobayashi, Y. Ogihara, and S. Shibata, *Tetrahedron Letters*, 5557 (1968).
11) N. Kobayashi, Y. Iitaka, and S. Shibata, *Acta Cryst.*, **B26**, 188 (1970).
12) Coordinates of atoms were adopted from (+)-dibromodehydrotetrahydrorugulosin, a more rigid derivative, which X-ray analysis was performed (ref. 11).

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