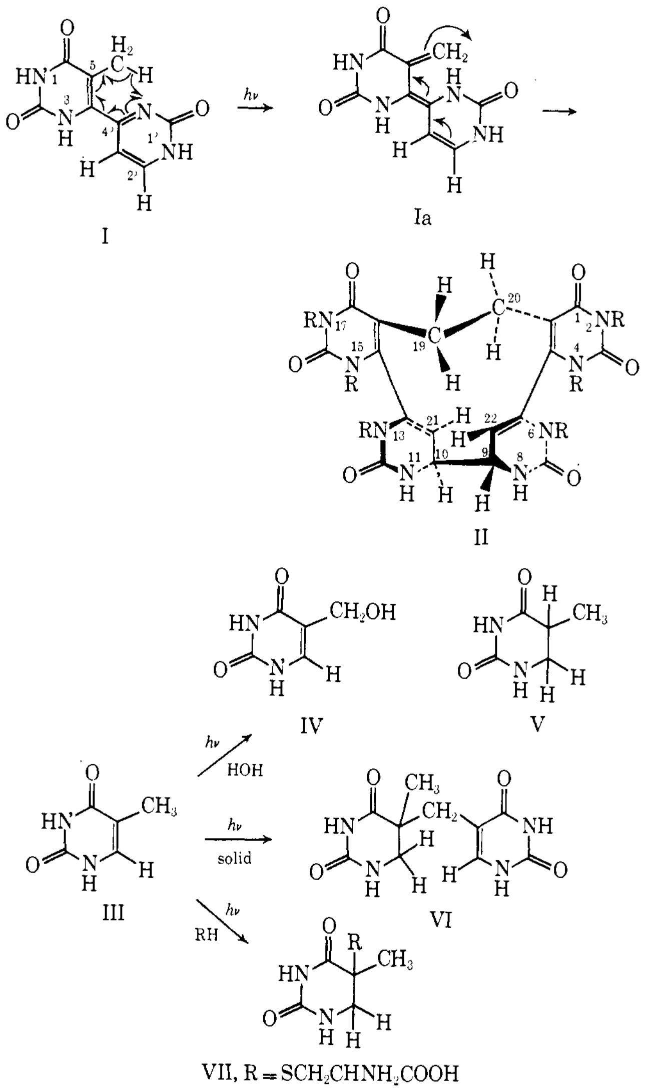
Scheme I



analogous to the well-known Norrish type II γ-hydrogen abstraction reactions of carbonyl compounds[8] and similar to the photochemical alloxazine–isoalloxazine transformation.[9] The resulting conjugated triene intermediate Ia should be a planar molecule. However, a molecular model shows that the exocyclic methylene group is forced out of the plane of the molecule and may be quite reactive. Thus, dimerization in a concerted manner ensues with another Ia approaching either from the same side to give a cis-syn dimer or from the opposite but stereochemically favored direction to yield a trans-syn isomer. Interestingly, the molecular model shows that the head-to-tail dimerization process is sterically unfavorable and explains why only dimers with syn or head-to-head configuration are obtained. While this mechanism seems to be the most likely choice, the detailed study is currently under way.

It should be noted that this hydrogen-transfer reaction may be related to the observation that irradiation (254 nm) of thymine III in aqueous solutions gives 5-hydroxymethyluracil (IV),[10] in DNA yields dihydrothymine (V),[11] and in solid state forms 5-thyminyldihydrothymine (VI).[12] In the presence of cysteine in aqueous solutions, irradiation of thymine results in the formation of 5-cysteinyldihydrothymine (VII). These reactions are of interest in the photo- and radiation chemistry of nucleic acids

Thus, the present finding indicates the occurrence of the hydrogen abstraction reaction in thymine derivatives. Also, it suggests that such a reaction could occur in DNA if the longer light wavelengths were absorbed by some chromophoric groups or by certain energy-transfer processes. Furthermore, reactions induced by thyminyl radicals may explain why 300–360-nm light causes inactivation in some biological systems.[13,14]

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Crystal and Molecular Structure of a Pyrimidine Phototetramer

Sir:

A product derived from an adduct of cytosine–thymine was separated from the acid hydrolysates of DNA irradiated with ultraviolet light *in vitro* and *in vivo*.[1] Its structure was characterized[2] as 6,4′-[pyrimidin-2′-one]thymine [$C_9H_8N_4O_3$] (I). Since I was obtained from the irradiation of DNA, its possible importance in the photobiology of nucleic acids should be investigated. However, only minute quantities of I can be isolated in these *in vivo* and *in vitro* experiments; thus, other approaches[3] must be developed in order to obtain sufficient amounts for further study. Consequently, it was found that the irradiation of a uracil–thymine mixture in frozen state can yield I in about 20 mg per run.[4] Upon irradiation of I in water with either 313- or 360-nm light, a novel photoreaction was discovered[5] involving 1,6-dimerization to form a large ring compound, II. Repeated methylation with methyl sulfate produced hexamethylated derivatives of two stereoisomers of II. The minor product (14%)

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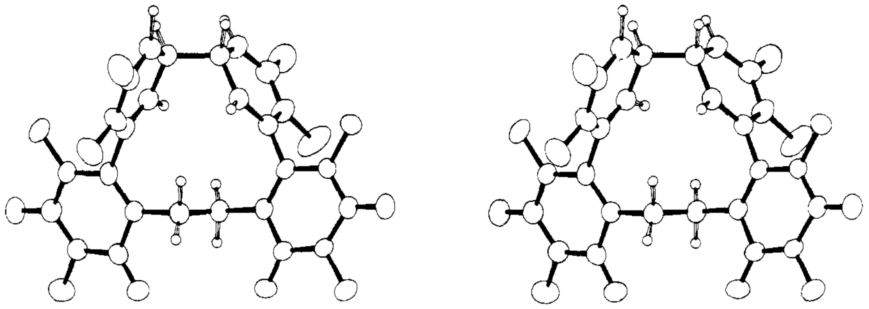

Figure 1. Stereodiagram of the pyrimidine tetramer (II).

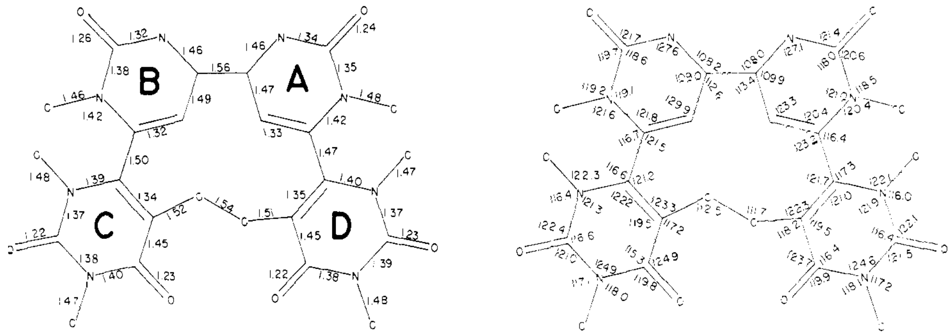

Figure 2. Bond distances and angles for the pyrimidine tetramer. The standard deviations are less than 0.009 Å.

shows a parent peak at *m/e* 524 [$C_{18}H_{10}N_8O_6 \cdot 6CH_3$] in its mass spectrum, confirming the dimeric nature.[5] A large crystal of the major product (86%) was used for X-ray diffraction analysis to establish its structural formula.

Single-crystal X-ray diffraction data were collected on a four-circle fully automated computer-controlled diffractometer. The space group is $P2_1/c$ with a = 7.117 ± 0.003, b = 21.348 ± 0.016, and c = 18.238 ± 0.006 Å, and β = 98.62 ± 0.10°. There are four molecules per unit cell and the crystallographic density is 1.38 g/cm^3. An E map computed with phases determined directly from the measured intensities by the application of the symbolic addition procedure[6] revealed the location of the 38 C, N, and O atoms of the molecule. Atomic coordinates and anisotropic thermal parameters were refined by a least-squares procedure. Ten of the 34 hydrogen atoms were readily located in a difference map, whereas the hydrogen atoms on the six CH_3 groups and three water of crystallization molecules were not sufficiently well defined. During the refinement, data having $|F_{\text{obsd}}| < 5.0$ and >50.0 were omitted to conserve computing time. The R factor (agreement between observed and calculated structure factors) for this limited set of 3035 independent data is 8.5% while the R factor for the complete set of 4350 data is 9.4%.

The conformation of the molecule II is illustrated in the stereodiagram in Figure 1. Head-to-head and tail-to-tail dimerization of I to form II was accomplished by the formation of a dimethylene bridge with the CH_3 groups on C-5 in rings C and D and by a trans junction between atoms C-6′ of rings A and B. The 12-membered ring of carbon atoms created by the dimerization has four unsaturated bonds with two cis and two trans conformations around the double bonds. Bond distances and angles (illustrated in Figure 2) and the positions of the hydrogen atoms (see Figure 1) clearly indicate the locations of the carbon–carbon double bonds. The plane through ring A is nearly perpendicular to the plane through ring D. The same relationship exists between rings B and C. Although it is not required by the space-group symmetry, the molecule effectively possesses a twofold axis of rotation. The unit cell was found to contain three molecules of water per molecule of tetramer. The water molecules and the C=O and NH groups in the tetramer molecule are involved in an extensive system of hydrogen bonding.

The establishment of the three-dimensional molecular structure of II would enhance the understanding of this unusual photochemical reaction mechanism.[5] Furthermore, cognition of this photoreaction gives credence to the earlier suggestions[7-9] that hydrogen abstraction from the methyl group of thymine may be of importance in photo- and radiation chemistry. This reaction also shows that this hydrogen abstraction may occur with 310–360-nm light.

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(11) Figure 1 should be seen with a three-dimensional viewer for printed stereophotographs, commercially available from either the Taylor Merchant Corp., 25 West 45th St., New York, N. Y. 10036, or Hubbard Scientific Co., 2855 Sherman St., Northbrook, Ill. 60062.

(12) Listings of fractional coordinates and thermal parameters for the pyrimidine tetramer will appear following these pages in the microfilm edition of this volume of the journal. Single copies may be obtained from the Reprint Department, ACS Publications, 1155 Sixteenth St., N. W., Washington, D. C. 20036, by referring to author, title of article, volume, and page number. Remit $3.00 for photocopy or $2.00 for microfiche.