Stereochemistry of Phytoene

By NAEEMA KHATOON, D. E. LOEBER, T. P. TOUBE, and B. C. L. WEEDON*
(*Department of Chemistry, Queen Mary College, Mile End Road, London* E1 4NS)

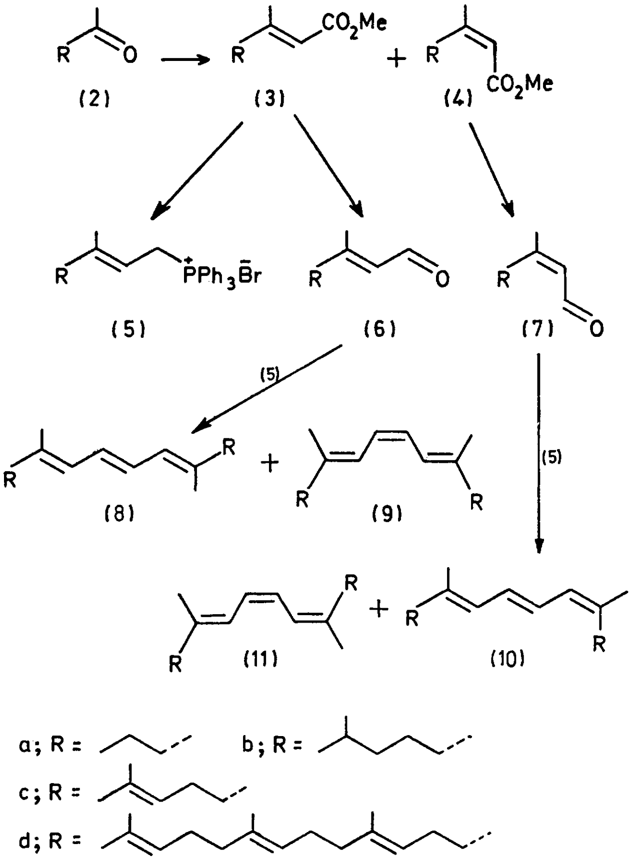
Summary Studies on models synthesised by stereochemically controlled routes show that the central triene chromophore in the common *cis*-isomer of phytoene (7,8,11,12,7′,8′,11′,12′-octahydrolycopene) has the *trans, cis,trans*-configuration, and that the phytoene from *Flavobacterium dehydrogenans* consists mainly of the all-*trans*-isomer.

PHYTOENE (1d) has been detected in many carotenogenic systems, and is generally recognised as the first conjugated polyene in the biosynthesis of carotenoids.[1a] The main isomer (ν_{max}† 763 cm^{-1}) isolated from carrot oil and from *Chlorella vulgaris* (mutant G.77) has been shown to possess the *trans*-configuration about all unconjugated non-terminal double bonds, and a *cis*-configuration about the central (15,15′-) double bond.[2] This *cis*-assignment has been confirmed by the coupling constant (*J* 10·6 Hz) computed from the 220 MHz n.m.r. spectrum.†‡ Identical n.m.r. spectra were obtained for the phytoene from *Phycomyces blakesleeanus*, *Rhodospirillum rubrum* (diphenylamine inhibited culture), and commercial tomatoes.§ Comparison of the 100MHz spectra with those of simple models allows a *trans*-configuration to be assigned to the 13,14- and 13′,14′-double bonds.

Condensation of pentan-2-one (2a) with methoxycarbonylmethyldiethylphosphonate gave the *cis*- (4a) and *trans*- (3a) esters which were separated by preparative g.l.c. These were severally converted into the corresponding alcohols, and thence into the Wittig salts and aldehydes. Reaction of the *trans*-Wittig salt (5a) with the *trans*-aldehyde (6a) (β-Me, δ 2·17) in butylene oxide at 100° gave a mixture (*ca.* 2 : 3) of the *trans, trans, trans*- (8a) and *trans, cis, trans*-triene (9a) which were separated by preparative g.l.c. (ν_{max} 964 and 766 cm^{-1} respectively; both had Me bands at δ1·72). Reaction of the *trans*-Wittig salt (5a) with the *cis*-aldehyde (7a) (β-Me, δ 1·97) gave (*ca.* 1 : 3) the *trans, trans, cis*- (10a) and *trans, cis, cis*-triene (11a) which were separated by t.l.c. on 30% $AgNO_3/SiO_2$ (ν_{max} 968 and 765 cm^{-1}, respectively; δ 1·72, 1·76; and δ 1·72, 1·80, respectively. The four isomers all had u.v. maxima† at 273, 282—284, and 295—296 nm, but with different relative intensities.

6-Methylheptan-2-one (2b) was similarly converted into the corresponding pairs of isomeric trienes. The u.v., i.r., and n.m.r. spectra of these mixtures were in excellent agreement with those from (2a). The n.m.r. spectra of the corresponding mixtures obtained by reacting *cis*- (7c) and *trans*-citral (6c) with the (*trans*-) geranyl Wittig reagent (5c)[2,3] indicated slight deshielding (0·02 p.p.m.) of the olefinic methyls by the unconjugated double bonds (a bathochromic shift of 2–3 nm in the u.v. maxima was also observed).

(1) RCMe:CH·CH:CH·CH:CMeR



The n.m.r. spectra of these models show that the band due to a methyl group attached to a *trans*-double bond at the end of the triene unit is independent of the stereochemistry of the rest of the chromophore. A methyl attached to a terminal *cis*-bond has a band further downfield (0·02—0·04 p.p.m. if the neighbouring conjugated double bond is *trans*, and 0·07—0·08 p.p.m. if it is also *cis*). Com-

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† I.r. spectra were run on liquid films; only the C–H out-of-plane deformations for the central, disubstituted double bonds are quoted. N.m.r. spectra were determined on solutions in carbon tetrachloride; measurements at 220 MHz were made by the S.R.C. N.M.R. Service (Runcorn). Unless otherwise indicated, n.m.r. bands quoted are from 100MHz spectra and refer to the methyl groups at the end of the central triene chromophore. All u.v. measurements were made on hexane solutions.

‡ The ^{13}C and 250 MHz proton spectra of phytoene have been studied by Dr. P. Granger (Nancy), personal communication.

§ Samples kindly provided by Dr. B. H. Davies (Aberystwyth): P. M. Bramley, B. H. Davies, and Aung Thang, *Phytochem.*, in the press.

parison of the n.m.r. (δ 1·74) and i.r. spectra of the common natural *cis*-phytoene with those of the models shows that the central triene unit must have the *trans,cis,trans*-configuration (9d). The coupling constants calculated for the olefinic protons ($J_{14,15}$ 12; $J_{14,15'}$ − 1·3, $J_{15,15'}$ 10·6; and $J_{14,14'}$ − 0·3 Hz) were in good agreement with those for (9a) [11·5, −1·4, 10·8, and −0·2 Hz, respectively; the corresponding values for (8a) were 11·0, −1·1, 14·6, and 0·1 Hz, respectively]. The shape of the u.v. curve resembled that of (9a) but the positions of the u.v. maxima (276, 286, and 298 nm) were those observed with the mixture (8c and 9c). It is also evident that the main phytoene isomer (δ 1·73; ν_{max} 958 cm^{-1}) from diphenylamine inhibited cultures of *Flavobacterium dehydrogenans* is the all-*trans*-isomer (8d).[1b,4]

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